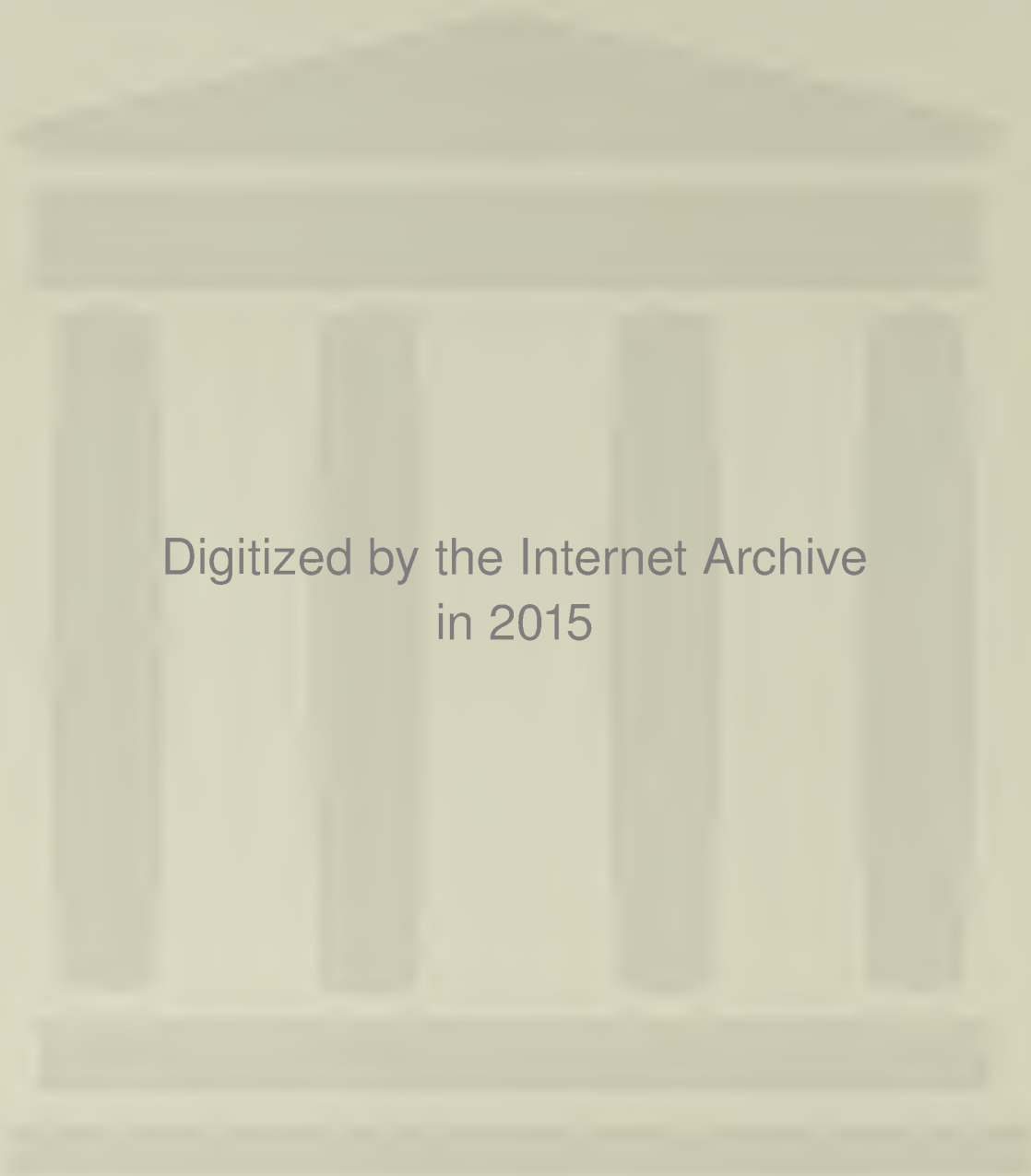
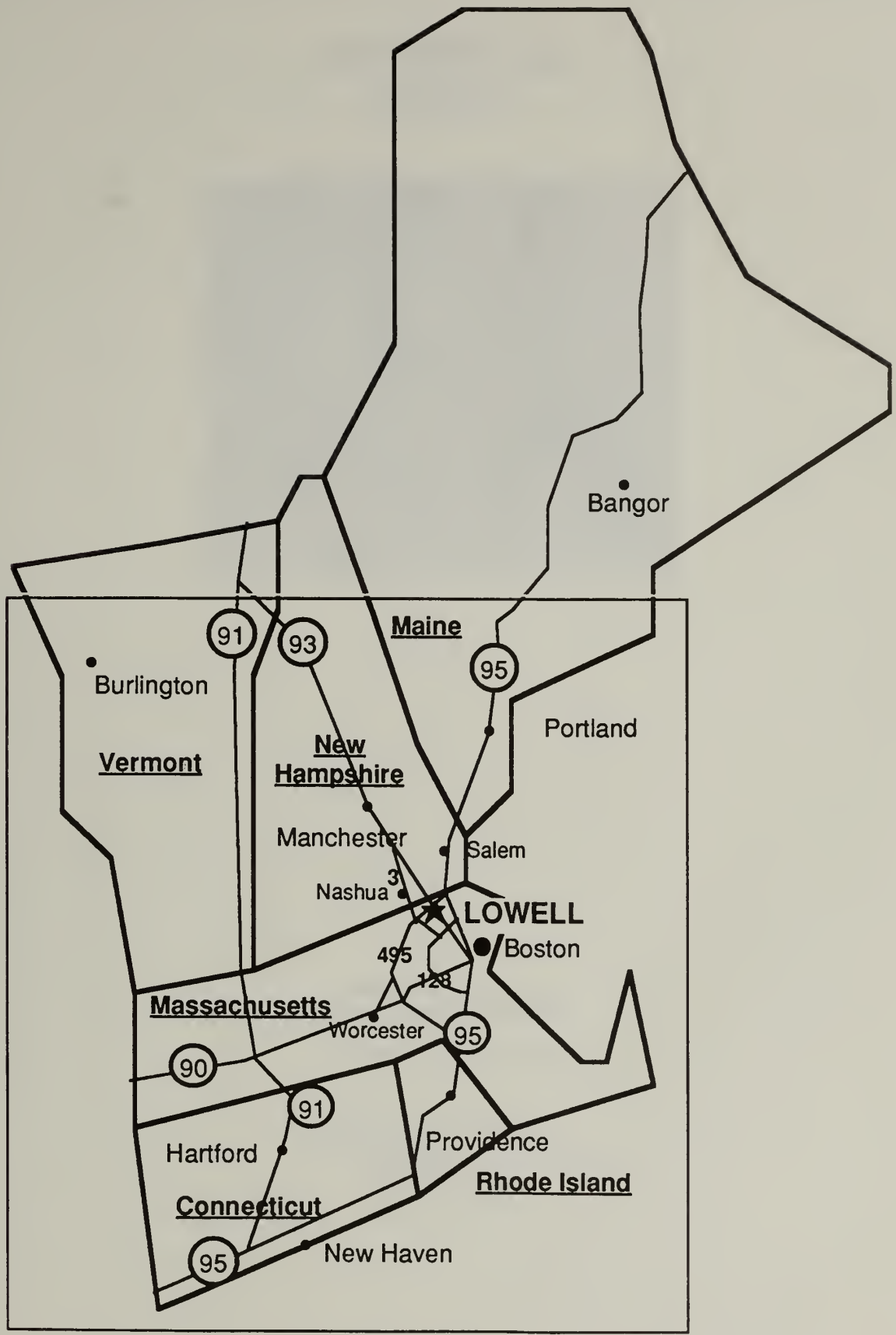
UNIVERSITY *of* LOWELL

1990/92 GRADUATE SCHOOL CATALOG

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UNIVERSITY OF LOWELL

One University Avenue
Lowell, Massachusetts 01854

Telephone: (508) 934-2380

Formed in 1975 by a merger of
Lowell Technological Institute,
established 1895, and
Lowell State College,
established 1894

Graduate Catalog
1990–1992

1990-1992
GRADUATE SCHOOL CATALOG
UNIVERSITY OF LOWELL

The University of Lowell is an Equal Opportunity/Affirmative Action University and does not discriminate in employment or access to programs or services on the basis of race, sex, color, national origin, religion, handicap or veteran's status and is in compliance with Title IX of the Education Amendments of 1972 and Section 504 of the Rehabilitation Act of 1973. Any inquiries and/or grievances may be referred to the Affirmative Action Officer, the Title IX Coordinator, the Handicapped Coordinator and/or to the Director, Office for Civil Rights, U.S. Department of Health and Human Services,Washington, DC.

This catalog was prepared well in advance of its effective date; as a result, it is possible that the course descriptions may vary to some extent from actual course content due to advancements in the discipline or for other reasons. Therefore, the descriptions that are given are provided for information rather than as a contractual obligation.

The Graduate School and the University of Lowell are not responsible for statements or agreements entered into or made by any University official or faculty member which do not conform to the rules and regulations in this catalog and/or which have not been approved by the Graduate Dean.

Reporting Correct Address

It is important that students report address changes on special forms provided for that purpose in the Graduate School Office. All correspondence, grades, etc., will be sent to the latest mailing address on file.

THE BOARD OF TRUSTEES OF THE UNIVERSITY OF LOWELL RESERVES THE RIGHT TO WAIVE, AT ITS DISCRETION, ANY OF THE RULES, REGULATIONS, AND/OR FEES STATED HEREIN AND TO CHANGE ANY OF THE SUBJECTS OR CURRICULA, OR PORTIONS THEREOF, WITHOUT PRIOR NOTICE.

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Programs Offered

The University of Lowell Graduate School offers graduate programs in the following areas:

Doctor of Philosophy (Ph.D.)

Chemistry - (options: Polymer Science, Polymer Science/Plastics Engineering, Environmental Studies, and Biochemistry)
Physics - (options: Energy Engineering, Applied Mechanics, and Radiological Sciences)

Doctor of Science (Sc.D.)

Computer Science
Work Environment - (options: Industrial Hygiene and Occupational Ergonomics)

Doctor of Education (Ed.D.)

Language Arts and Literacy
Mathematics and Science Education
Leadership in Schooling

Doctor of Engineering (Eng.D.)

Electrical Engineering
Mechanical Engineering
Plastics Engineering

Certificate of Advanced Graduate Study (C.A.G.S.)

Reading and Language
Administration, Planning and Policy
Curriculum and Instruction (option: Technology and Learning Environments)

Master of Arts (M.A.)

Community and Social Psychology
Criminal Justice

Master of Science (M.S.)

Biological Sciences (option: Biotechnology)
Chemistry
Clinical Laboratory Sciences (options: Clinical Research, Clinical Administration, Clinical Education)
Computer Science
Environmental Studies
Health Services Administration (options: Health Care Management, Health Promotion Management)
Mathematics - (options: Applied Mathematics, Mathematics for Teachers, Scientific Computing, and Statistics and Operations Research)
Nursing - (options: Administration of Nursing Services, Gerontological Nursing, and Family and Community Health Nursing)
Physics - (option: Optics)
Plastics
Polymer Science
Radiological Sciences and Protection
Work Environment - (options: Industrial Hygiene and Occupational Ergonomics)

Master of Science in Engineering (M.S. Eng.)

Chemical Engineering
Civil Engineering - (options: Geotechnical, Structural, Transportation, Water Resources and Environmental, and Geotechnical / Environmental)
Computer Engineering
Electrical Engineering - (option: Opto-electronics)
Energy Engineering - (options: Fission, Fusion, Solar, Geothermal)
Materials Engineering
Mechanical Engineering
Plastics Engineering - (options: Plastic Materials, Design, Processing, Coatings and Adhesives, and Fiber/Composites)
Systems Engineering

Master of Education (M. Ed.)

Curriculum and Instruction - (options: Elementary Education, Secondary Education, Art Education, English as a Second Language, Bilingual Education, and Technology and Learning Environments)
Administration, Planning and Policy
Reading and Language

Master of Music (M.M.)

Performance (option: Conducting)
Music Education
Musicology
Music Theory/Composition

Master of Business Administration (M.B.A.)

Master of Management Science in Engineering (M.M.S. Eng.)

Manufacturing Engineering

Accreditation and Professional Memberships

The University of Lowell is accredited by the Commission on Institutions of Higher Education, New England Association of Schools and Colleges. Professional programs are also individually accredited by the following national associations which evaluate at the graduate level:

American Assembly of Collegiate Schools of Business
National Association of Schools of Music
National Council for the Accreditation of Teacher Education (Elementary, Secondary, and Music Education)
National League for Nursing

The University of Lowell is also a member in good standing of the following associations of higher education:

American Assembly of Collegiate Schools of Business
American Association of Colleges for Teacher Education
American Association of Colleges of Nursing
American Chemical Society
American Council on Education
American Physical Therapy Association
American Society for Engineering Education
American Society of Allied Health Professions
Association for Gerontology in Higher Education
Association for State Colleges and Universities
Association of University Programs in Health Administration
College Entrance Examination Board
Council of Colleges of Arts and Sciences
Council of Graduate Schools in the United States
Interstate Certification Compact
Massachusetts Association of Colleges of Nursing
National Association for Industrial Technology
National Association of Summer Sessions
National Association of State Directors of Teacher Education and Certification
National League for Nursing Council of Baccalaureate and Higher Degree Programs
National University Continuing Education Association
New England Board of Higher Education

University Profile

History

The University of Lowell was established by Chapter 1175, General Laws of the Commonwealth of Massachusetts, through a merger of Lowell State College and Lowell Technological Institute. These two institutions were established in the last decade of the 19th century as single-purpose institutions and were charged with providing instruction in those theories and practical arts which were most suitable to the teaching profession and the textile industry. Lowell State College was chartered by the General Court of the Commonwealth on January 6, 1894 as a teacher-training institution and was assigned the responsibility for providing "the most thorough knowledge of the branches of learning required to be taught in schools, the best methods of teaching these branches, and right mental training." In 1932, the institution was made a four-year college and was granted the right to confer baccalaureate degrees. In 1960, the college became a multi-purpose institution by initiating non-teaching programs in the liberal arts. During the next decade and a half the college continuously extended its mission and curriculum offerings at both the graduate and undergraduate levels and was authorized to offer degree programs in education, the health professions, the liberal arts, sciences, and music.

From the time of its origin in 1895 as a proprietary textile school, Lowell Technological Institute provided educational programs of an applied and practical nature. "Science and art will be taught," the original prospectus pointed out, "with a view to industrial and commercial application" and for "the purpose of improving any special trade or of introducing new branches of industry." The control of the school was transferred to the Commonwealth in 1918, and in 1928 it was granted collegiate status. In 1953, it became a broadly based technological institute. During the last two decades, the institute phased out its textile curricula, extended its curriculum offerings in engineering and technology, the pure and applied sciences, business administration and industrial management. In 1965, Lowell Technological Institute received authorization to offer degrees through the doctoral level.

The merger of Lowell State College and Lowell Technological Institute brought together two multi-purpose institutions of differing character and orientation and made possible the creation of a comprehensive university whose strengths and resources are manifestly greater than those possessed by the two separate institutions. The University of Lowell's graduate students now account for almost 3,000 of the 14,500 students enrolled in both state-supported and Continuing Education programs, and the graduate faculty numbers approximately 300 of the 500 members of the University's teaching staff. The combined institutions offer diversified graduate programs in the fields of business administration, education, engineering, health professions, music, pure and applied sciences, criminal justice, and psychology.

Purpose of the University

Recognizing its responsibility as a publicly supported institution of higher education, the University of Lowell seeks to discover, integrate, and transmit knowledge to meet the economic, professional, and cultural needs of the Commonwealth. To these ends, the University offers undergraduate and graduate degree programs in business, education, engineering and technology, health professions, social sciences, music, and the pure and applied sciences. The University maintains a wide range of continuing education programs for those individuals who cannot attend classes on a full-time basis because of family responsibilities or economic constraints and for those who seek continuing personal and professional development. The University also provides special business, industrial, health, scientific, and educational seminars and training programs in cooperation with both the public and private sectors. Through these educational programs, the University strives to develop individual capacities for rational analysis and effective decision making and to create a basic understanding of our cultural and scientific heritage. Finally, the University has a special mission to continue the positive implementation of Equal Opportunity/Affirmative Action, Title IX, thereby ensuring that all students and employees, and in particular, minorities, veterans, women and handicapped persons are guaranteed the benefits of a just and equitable educational system.

Mission of the Graduate School

The mission of the Graduate School at the University of Lowell is to provide a fertile and stimulating environment for teaching, learning, research, dissemination of professional skills, and promotion of the pursuit of knowledge. To this end, the Graduate School encourages the assemblage of scholars, scientists, and artists under whose direction graduate students can pursue advanced studies and carry out research activities. The quality of the graduate faculty involved in these programs is the most important factor in the establishment of excellence. In an endeavor to accomplish the mission of the Graduate School, each professor aspires to be a creative and skillful teacher.

The central purpose of the University is to enhance the quality of life in our society through knowledge. The role of the Graduate School in this overall objective is to educate individuals with superior ability in the expertise of their chosen profession and to develop in them the competence and motivation which will enable them to realize their personal and community potential. The Graduate School recognizes its responsibility as a publicly-supported institution of higher education to work to develop the technical expertise of the region and to advance the frontiers of knowledge through research.

Location

The University of Lowell is located 25 miles northwest of Boston and is situated on the northwestern periphery of the City of Lowell. The two major campuses lie on opposite sides of the Merrimack River, the power source which gave rise to America's first industrial city. In addition, a third campus, designated "West" is located in North Chelmsford at the site of the former Middlesex County Training School. This campus houses the College of Education. The North Campus is the primary location for the Sciences, Engineering, and Management and is a short distance across the river from the Research Foundation and Fox Student Union Building. The latter facility is the center for student campus life, including many activities open to graduate students. The South Campus is situated on a bend of the Merrimack River approximately one mile upstream from the North Campus and occupies an elevated site midway between the mouths of the historic Middlesex and Pawtucket Canals. The Colleges of Music and Health Professions are located on the South Campus as well as most programs in the liberal arts. The physical area of the University campuses includes 45 buildings on 145 acres of land. The campuses are easily accessible from US Route 3 and Interstate 495, by train from Boston (Massachusetts Bay Transportation Authority), and by local and interstate bus lines (Massachusetts Bay Transportation Authority, Continental, and Vermont Transit).

In addition to being the home of the University of Lowell, Lowell is a city rich in heritage. Due to its prime location on the Merrimack River, it became the first great industrial city in the United States. Different immigrant groups migrated to Lowell to work in the mills that were built along the river. Today, the descendants of these varied ethnic groups plus many new arrivals make up much of Lowell's population. The city is the site of an Urban State and National Park, illustrating Lowell's industrial and multi-ethnic history.

University Libraries

The University libraries consist of the Alumni/Lydon Library, O'Leary Library, the Center for Lowell History and the West Campus Curriculum Center. The O'Leary Library on the South Campus has holdings in the humanities, social sciences, education and music. On the North Campus the Alumni/Lydon Library specializes in materials in science, technology and business. The Center

for Lowell History includes rare books and artifacts relating to the history of the City of Lowell and the surrounding region. The West Campus curriculum center contains resources for the programs in Education offered at the West Campus. The reference departments provide interlibrary loan services, computer and manual literature searches and end-user database searching through the use of CD-based systems. They also offer special bibliographic instruction and ready reference service. The University libraries have been designated as a United States Government depository for unclassified documents. Information and handbooks about the University libraries are available at the circulation and reference desks of the libraries. Information about the libraries can also be found by using the Videotex system that can be accessed through the public terminals.

Media Services, a division of the University libraries, provides presentation, production and consultation related to instructional media. Media centers are located on both the North and South campuses. The O'Leary Library incorporates a media center that can accommodate over 230 students in five instructional and presentation areas. The Alumni/Lydon Library can accommodate over 140 students in two instruction and presentation areas.

The University libraries have 23 professional librarians, an acquisition budget of approximately $800,000 and a total budget of 3.2 million dollars. The collections consist of 383,712 bound volumes, 3,425 periodicals subscriptions, 611,799 microfiche and films, 318,697 government documents and approximately 60,000 items in various formats that are available in the Media Services Department and the Center for Lowell History. An on-line catalog allows users to find information on library holdings through the traditional author, title and subject searching techiques, and also through other search methods that would not be possible with a card catalog.

Resources and Service Facilities

Computer Resources

The University of Lowell provides students and faculty with one of the largest, most sophisticated academic computing environments in the United States. Over 2500 terminals, microcomputers and workstations are linked to more than 150 multiuser computer systems via a university-wide communications network based on both Ethernet and proprietary protocols. The recent cutover of an integrated voice/data switch will allow substantial expansion of this data capacity to all segments of the university population. It is the policy of the University of Lowell to issue computer accounts to all University students; public access clusters of terminals and micro-computers are distributed around the campus.

The University maintains large separate central facilities for general purpose academic and administrative operations. These systems consist of clusters of DEC VAX 8650's, 8700's and 8800's running the VMS operating system and support over 600 concurrent terminal connections. The systems provide access to a comprehensive selection of modern compilers, editors, data base systems, libraries (SPSS, IMSL, NAG, ...), software development tools and commercial grade application packages (SDRC IDEAS packages, DEC software library, SPICE, ANSYS, FEAP, MOLDFLOW,...). The university library system is fully computerized and accessible via the campus network. The University is an active participant in CSnet, BITnet and several other computer networks.

These central systems also support university-wide electronic mail, electronic conferencing and videotext capabilities; access to high speed, high quality laser output is also available via this cluster. The University has recently undertaken the replacement of its word processing systems with micro-computers that are linked to the academic cluster for document exchange and file storage.

Dedicated computing facilities are also distributed throughout the colleges and academic departments. The heaviest concentrations of dedicated terminals, workstations and super minicomputer systems are installed in the Engineering and Computer Science areas. Engineering resources include: file and compute services provided by a VAX cluster (8550 and 6220 systems), several microVAX's and a Data General MV/10000 supporting over 150 graphics terminals and workstations. Special purpose systems include: an HP 1000 for real-time structural analysis, VAX 8350 and Vaxstations for VLSI and semiconductor design, an ALLIANT FX/8 for computational fluid dynamics and several MASSCOMP systems for real time applications.

Support for the Computer Science Department's research and academic programs includes: DEC VAX's (8550, 8350's, microVax's), Data General MV's (15000, 7800's), Sequent Balance 21000, Symbolics 3600's, LMI LAMBDA's, Intel Hypercube, DEC and DG RISC systems and a number of special purpose smaller systems. All major systems and some 90 workstations are interconnected on several LAN's and the University broadband network.

Each of the other colleges have their own dedicated facilities to supplement the central computer center. There are more than 1500 microcomputers in use. A network of over 300 workstations (DEC, Apollo, SUN, DG and Calcomp) support design, software development and analysis needs. Very high performance graphics mini supercomputers from Stellar, Ardent, Apollo and PIXAR are available as distributed resources for large computing and graphics intensive tasks.

Academic Center for Health Promotion

The Academic Center for Health Promotion is designed to mobilize the institution's resources for teaching, research, and service, and to focus these on the region's needs to improve the quality of life through helping individuals, families, and communities to maintain the highest level of health possible. This center will provide the health care industry with a pool of talented persons (students, faculty, and researchers) who will contribute to addressing health care problems through cooperative programs with health care practitioners, in research, internships, consultation and exchange.

Center for the Arts

The University of Lowell Center for the Arts presents a Performing Arts Series of international, national and regional artists in music, theater, dance and jazz and a Children's Discovery Series of professional touring events for children as well as many events during the school day. The Center provides support for visual arts exhibits, gives technical support to extra-curricular student-initiated events and presents masterclasses and symposia on arts topics. The Center presents events in Durgin Hall on south campus, which contains a 980 seat theater, and other venues on campus and in the city. Student tickets for reserved seats can be purchased in advance at half price, or at rush price as available, thirty minutes before performances of selected events. Tickets or information: (508) 934-4444.

Center for Field Services and Studies

The University of Lowell Center for Field Services and Studies is an initiative within the College of Education. It was formed in 1984 to create a new level of sustenance for the region's elementary and secondary schools. By promoting and expanding a variety of public education, university, and corporate partnerships, the Center addresses six major priorities:

1. Research and development for short and long range improvements in the Lowell Public Schools.
2. Staff development offered to schools in the entire northeast region of the Commonwealth. Particular attention is given to improved instruction in mathematics, science, and bilingual education.
3. Student intervention programs to discourage students from dropping out of school and to encourage them to prepare for college and careers. The Lawrence College Prep Program and New Horizons for Lowell are examples of such direct service efforts.

4. Facilitating grant opportunities that meet the needs of public schools in the region.
5. The Network on Restructured Schools- a member-initiated group within the national Association for Supervision and Curriculum Development.
6. The Instructional Network, a model project linking the University of Lowell to local schools using telecommunications.

Center for Lowell History

The University of Lowell Center for Lowell History was established at the Patrick Mogan Cultural Center to promote and assure the safekeeping, preservation, study and research of items in unique subject areas, particularly those related to the Merrimack Valley and the University of Lowell.

Center for Productivity Enhancement

The University of Lowell Center for Productivity Enhancement is a unique collaboration of students, faculty and staff from various departments and research laboratories, working closely with the government and Massachusetts industry to unite research efforts and industry demands for potential production. The Center aims to maximize the efficiency of manufacturing and production in regional industries through the development of state-of-the-art technology using robotics, machine vision, and computer graphics, while providing a valuable learning atmosphere for students and industry leaders alike. The Center for Productivity Enhancement is responsible for developing graphics, imaging, and windowing systems standards for the American National Standards Institiute, and has also recently been awarded a patent for Vibrassy, a method of mechanical insertion for tight fit parts, developed within the Center.

The Imaging Research Lab (IRL) in the CPE has undertaken numerous research efforts in the area of graphics and imaging hardware. The Lincoln Logs Factory of the Future, a completely in-house constructed, two-work-cell factory, is a working model of integrated design manufacturing, employing robotic assembly, machine vision, robotic scheduling and expert systems through the design and construction of Lincoln Log structures. The Work Environment Laboratory is yet another facet of the CPE which explores the problems and solutions of the impact of high technology on work environments, and addresses the need to maintain the health and safety of the workforce in Massachusetts industry. These projects, and numerous others within the CPE, stress the importance of combining industry and academia for solving today's problems concerning both the development and introduction of advanced, cost-effective manufacturing methodologies in the United States industrial arena.

Durgin Hall

In 1976 the University opened this major complex for the performance, practice and teaching of music. Beautifully situated on the banks of the Merrimack River, Durgin Hall contains a concert hall with seating for over one thousand and features an acoustical shell on the stage, an orchestra pit which can be raised and lowered, and a lighting console of sufficient flexibility to permit production of any type of concert from chamber music to opera or any type of theater from musicals to classical drama. The recital hall, which seats 250, is ideal for student and faculty recitals and houses a Schlicker tracker organ of eleven ranks. Seventy-two practice cubicles, twelve classrooms and sixteen teaching studios, two recording studios, two electronic piano laboratories and an electronic music studio provide basic facilities to study, teach, and perform.

Energy Center

The University of Lowell Pinanski Energy Center is a modern educational and research facility. The Center is housed in a three-story building devoted to research and instruction in various fields of science and engineering. The two major facilities of the Center include a 1 Mw pool-type research reactor and a 5.5 MV van de Graaf accelerator. The reactor is used for graduate research through activation analysis of various environmental, geologic and industrial process samples, and through studies of radiological particle behavior; it is also used for training and education in such fields as engineering, radiochemistry, radiation protection, and instrumentation. The accelerator is used mainly for graduate research in nuclear structure and material engineering, particularly as applied to gathering data for fast breeder reactor design.

Although financed by the Commonwealth mainly to serve the curricula of the University, the facilities are available by arrangement to other Massachusetts colleges and universities, and to industrial firms for a variety of research and educational purposes. The Center is also equipped with an assortment of teaching and research laboratories.

Institute for Plastics Innovation

The Institute for Plastics Innovation is an initiative of the Plastics Engineering Department. This state-of-the-art, graduate-level, plastics manufacturing research facility focuses on four areas: technology transfer, training and education, institute-initiated research and supplementary research services.

The applied research programs are aimed at coordinating existing technology and developing new technology in the areas of product design, materials research, processing, and machinery and equipment development. Research projects include: lowering manufacturing costs through process control; enhanced performance of manufacturing equipment using improved design and development of sensor modules; increased reliability of product design by integrating and modifying software programs, and setting guidelines for standards in order to judge the efficiency of a process or product. The current equipment processing emphasis is in the areas of injection molding, extrusion and blow molding.

The Institute also reviews, assembles and consolidates technology developments in many industrial areas and assesses the potential of these developments for plastics manufacturing. A major aspect of the Institute includes technology transfer. Faculty within the Institute provide training and technology updates to industrial personnel through continuing education classes and on-site consultation.

Photovoltaic Program

The University of Lowell Photovoltaic Program began in 1987 with funding from the United States Congress to provide technology services to the Massachusetts Photovoltaic Center, a Center of Excellence funded by the Commonwealth of Massachusetts. An outdoor photovoltaic systems laboratory and demonstration facility includes two water pumps, a grain drier, and a model health clinic, all powered by photovoltaics. Faculty from various departments use Photovoltaic program facilities and grants to design, build and test system components and photovoltaic cells. The program has produced design manuals, a solar irradiation database, and photovoltaic system design programs which run on personal computers.

Research Foundation

The Research Foundation was established in 1950 as a not-for-profit organization which operates with income derived from research funded by private industry, foundations, and government agencies. The Foundation contains major support facilities for faculty and student research projects, and provides a mechanism for the administration and fiscal management of all academic grants and contracts for research and training.

As part of its close cooperation with the University, the Research Foundation employs both graduate and undergraduate students from the University on a part-time basis. These students gain practical experience which often becomes part of an advanced degree program. Among the significant areas of research and development are sponsored programs in intelligent manufacturing, atmospheric physics, tropical diseases, chemistry, plastics and polymers, biology, electronics, nuclear engineering and training, as well as programs in radiation health physics,

composite materials, work environment, management and economics. In addition to the research which is carried out on campus, research projects also have been conducted in Thailand, Belgium, Greece, Italy, Germany, Algeria and other parts of the world where the Unversity is becoming known for its significant expertise.

The Research Foundation operates two auxiliary, for-profit enterprises, the Metrology Division and the Testing Division. The Metrology Division provides electronic and mechanical repair and calibration services (with traceability to the National Institute of Standards and Technology) to businesses and industries throughout New England. This service is available at the Foundation and can also be performed at a customer's site with a completely equipped mobile calibration laboratory. The Testing Division is a material testing laboratory which draws its support from private business and industry. Testing is performed on all types of materials, from fibers and liquids to metals and plastics, and can be tested for composition strength, flexibility and resistance to wear, among other standards.

The following laboratories are housed at the Research Foundation: The Center for Atmospheric Research, The Center for Tropical Diseases, The Submillimeter Modeling Laboratory, and The Small Business Development Center.

Toxics Use Reduction Institute

The Toxics Use Reduction Institute is a multi-disciplinary research, education and policy center established at the University of Lowell in 1989. Beginning in the fall of 1990, the Institute will sponsor research, conduct training, and provide technical support to governments to promote reduction in the use of toxic and hazardous chemicals in industry and commerce.

Tsongas Industrial History Center

The Tsongas Industrial History Center, located in Lowell's Boott Mills, is a joint project of the University of Lowell and the National Park Service.

Scheduled to open in 1991, it will be a "hands-on" education center, designed to encourage the teaching and understanding of industrial history. Students and teachers will have an opportunity to take part in role playing and interactive exhibits focused on such topics as the canal system, work environments, design, labor and immigration, and the power loom.

In addition to the planned experiential learning activities, the Center offers special programming, teacher training (through the College of Education), curriculum development, and the use of its growing resource center, which already contains over 700 volumes, videos, and computer software.

Continuing Education and Summer School

The Division of Continuing Education provides opportunities for graduate study in two summer sessions offering courses in many of the degree programs, summer day workshops and special projects.

All Continuing Education programs are self-supporting and are conducted at no cost to the Commonwealth. Complete information is available in the Continuing Education Office. The University of Lowell is a member of the National University Continuing Education Association (NUCEA) and the National Association of Summer Schools (NASS).

Student Services

Housing

Single students may apply for residency in the Bridge Street Building, a recently renovated apartment building located in the City of Lowell only a short distance from the North campus. Bridge Street accommodates 73 graduates in fully furnished three and four person apartments with each resident having a private bedroom. Each apartment has a complete kitchen, and laundry facilities are located on the premises.

Married students may apply for residence in the East Meadow Lane apartments, located only a short distance away from the North campus. East Meadow Lane offers 48 unfurnished one and two bedroom apartments complete with refrigerator, stove, dishwasher and air conditioner.

A list of off-campus housing may also be obtained from the Office of Residence Life in Cumnock Hall. The University does not sanction or otherwise endorse any housing off campus and accepts no responsibility for student residences other than university-supervised facilities. Students who wish to obtain an application for either Bridge Street or East Meadow Lane or an off-campus housing list should contact the Office of Residence Life in Cumnock Hall or call at 508-934-2100.

Health Services

The University Health Office is open 8:00 am to 4:30 pm, Monday through Friday. It is located at 30 Standish Street behind the Alumni/Lydon Library, (934-4991).

All students with a completed health record on file at the Student Health Service office are eligible for services. Services include first aid, care of minor illnesses, monitoring of chronic illness and health counseling. Services are provided by a physician, nurse practitioner, or registered nurse with referrals to and consultation with specialists, as appropriate.

Medications prescribed by the Health Service must be filled at a pharmacy of the student's choice and at the student's expense.

A limited amount of laboratory tests can be performed at the Health Services Office for a slight fee. All other tests are referred to area laboratories, and the student is responsible for fees incurred.

When the Health Service is closed, medical service may be obtained at one of the three local hospitals.

Graduate Student Association

The purpose of the Graduate Student Association is to enhance the academic, social, and economic advancement of all graduate students, to represent the graduate student body in university affairs, to establish closer interdepartmental relations among graduate students, faculty, and the administration, and to promote the common interests and better communication among graduate students and with other components of the university community. All graduate students who pay the Graduate Activity Fee are members of this organization. All colleges offering graduate programs are represented in its governing bodies.

Tuition and Fees Per Semester

Tuition for Massachusetts residents ..... $79.17 per credit up to a maximum of $950.00
Tuition for out-of-state residents ..... $247.92 per credit up to a maximum of $2,975.00
Tuition for residents of other New England states eligible for the New England Regional Student Program (see "apple book" for details) ..... $118.75 per credit up to a maximum of $1,425.00

Fees paid by everyone

Registration Fee $25.00
Academic Services Fee ..... $13.50 per credit (up to a maximum of $162.00)
Student Activity Fee ..... Full-time $30.00 Part-time $21.00
Recreational Services Fee .... $ .75 per credit (up to a maximum of $9.00
Student Union Fee ..... $2.00 per credit (up to a maximum of $25)
Escort Service Fee $2.00
Operating Fee ..... $13.67 per credit (up to a maximum of $164.00)
Non-Academic Student Services Fee..... $2.50 per credit (up to a maximum of $30/semester)

Fees paid by students in specific programs only

Engineering & Computer Science Fee ..... $13.30 per credit (up to a maximum of $160.00)
Pure & Applied Science Fee ..... $11.15 per credit (up to a maximum of $134.00)
Health Professions Fee ..... $7.70 per credit (up to a maximum of $92.00)
Management Science Fee .... $5.60 per credit (up to a maximum of $67.00)
Liberal Arts Fee ..... $5.60 per credit (up to a maximum of $67.00)

Special purpose fees

Laboratory Fee ..... $32.00 per course (for courses with 800 section numbers)
Health Insurance Fee** ..... $217/year (waivable with evidence of comparable coverage)
International Student Fee ..... $38.00 per semester
Continued Advisement ..... $60.00 (plus registration fee)
Clinical Supervision Fee $110.00
Applied Music Fee ..... $25.00/credit hour, up to maximum of $300.00
Commencement Fee $55.00

Dormitory Charges:

Single Student Housing $290.00/month
Married Student Housing ..... (2-bedroom) $490.00/month (1-bedroom) $440.00/month

* *The fees and tuition charges were effective for September 1990 and are subject to change without notice by the Board of Trustees. Applicants in subsequent years should anticipate substantial increases in tuition and fees.*

New England Regional Student Program

The University participates in this reciprocal program in which qualified and legal residents of New England may attend graduate school and pay 150% of in-state tuition charges. Applicants are considered for unique and distinctive graduate level studies not available in their home state university system. Full details regarding eligible programs are available from the New England Board of Higher Education, 45 Temple Place, Boston, Massachusetts 02111 or at the University of Lowell Graduate School office.

Refund Policy

Graduate students are permitted to withdraw during the first week (i.e., five class days) of the semester without penalty and receive a full refund if a written withdrawal request is received by the Graduate School during that time period. There will be no refund for graduate students who withdraw from class(es) or from the University after the fifth day of the semester.

This policy permits students to attend the first class to determine the course level, work load, etc. and to drop the course without charge. Students who attend the second class week are, in effect, making a commitment to pay the full amount of tuition and fees.

Health Insurance

Massachusetts law requires that all university students in the Commonwealth be covered by health insurance, as follows: Full-time matriculated students must purchase both accident and health insurance or, if they are already covered by another policy, provide a petition for waiver form by the deadline designated in the semester calendar. Waiver forms are available at the Graduate Office and must be returned to Accounts Receivable, Dugan Hall, South Campus or there will be a health insurance charge on the student's bill. Part-time matriculated students may elect to purchase the health insurance. Non-degree students will not be charged for health insurance. An optional major medical plan is available to matriculated students.

Veterans

The University of Lowell is approved for Veterans Administration benefits. Eligible veterans should obtain the necessary application from the Veterans Administration and present it to the Graduate School office at or before registration. Veterans Administration regulations state that a veteran must be working toward an advanced degree in order to be eligible for benefits. A veteran cannot be certified for individual courses as a non-matriculated student.

All recipients of veterans' benefits are required to certify attendance each month by signing a list available in the Graduate School office. Failure to do so will be reported to the Veteran's Administration at the end of the month.

Financial Assistance

Financial Aid

Financial need will be determined after the student has filed with the College Scholarship Service, Princeton, New Jersey, the FAF (Financial Aid Form) or GAPSFAS (Graduate and Professional School Financial Aid Service), available from the Financial Aid Office. The major source of financial aid recommended to students is the Stafford Loan Program (also known as GSL loans). These need-based loans, which are obtained through local banks, allow the student to borrow up to $7,500 at a low interest rate per year for graduate work. In addition, graduate students may apply for the Supplemental Loans for Students (SLS). Non-need-based loans (credit worthiness), such as TERI Supplemental Loan, Alliance, and Massachusetts Family Education Loan (MELA), are also available. Information regarding interest rates, repayment schedule, and eligibility for these loans may be obtained from the Financial Aid Office or a participating lending institution.

Full-time graduate nursing students are eligible for federal nursing grants; information is available through the Department of Nursing.

The college-based financial aid available at the University of Lowell is the National Direct Student Loan, and the College Work Study Program. To be considered for these programs, students must complete and return the University of Lowell Financial Aid Forms to the Director of Financial Aid at the University. For more information, students should call or write the Office of Financial Aid in the McGauvran Student Union Building, South Campus (508) 934-4220.

Assistantships

A limited number of teaching assistantships are available for qualified full-time students. These are administered by the Graduate School but are assigned by the student's department.

Tuition is waived for all full-time graduate students who hold half or full assistantships. Teaching assistants who have served for two semesters are eligible for free summer school tuition the following summer. Stipends for 1990-91, range from $7,000. to $9,500., and the contract requires a commitment for the entire academic year. A student who signs a teaching assistantship contract after April 15th is legally bound to honor this agreement and may not accept an offer from another institution, in accordance with the 1988 Council of Graduate Schools resolution governing this matter.

A student who wishes to compete successfully for an assistantship should file his or her application for admission to a degree program as early as possible, checking the appropriate box on the application form. A student who is to receive an assistantship will be notified and sent a contract by the department. Reappointments in succeeding years are contingent upon satisfactory performance of duties as well as academic achievement. Master's degree candidates may hold an assistantship for a maximum of two years and doctoral candidates for a maximum of four years. International students are generally not eligible for assistantships until they have been at the University for one year.

Fellowships

Fellowships usually are available only for advanced graduate students and through special arrangement with individual research advisors. Full-time fellowships may include tuition waivers. These waivers must be obtained with a special form available at the Graduate School office and must be renewed before September every year. Students on fellowships and/or assistantships must be registered as full-time students.

Graduate Student Assistantships

A limited number of student assistantships are available in the departments. Student assistants are given specific assignments, such as administering laboratory quizzes or grading under the supervision of a faculty member. Students in this category are paid a specified sum per hour of work; no waiver of tuition is available.

Summer Research Fellowships

Summer Research Fellowships generally are available from the Research Council, a university committee composed of faculty and administration. These grants are used to help support graduate students carrying out their thesis research during the summer months. In order to qualify for this support, students write a research proposal which must be approved by a screening committee of the Research Council. The amount of this support varies, depending upon the funds available.

All queries concerning assistantships and fellowships should be directed to the graduate program coordinator in the student's department.

Admission Requirements

The general requirements for admission to graduate study at the University are listed below.

1. The applicant must have earned a baccalaureate degree or its equivalent from an accredited college or university.
2. The degree must have been earned with a satisfactory scholastic average to demonstrate that the applicant has had adequate preparation for the field in which graduate studies are to be undertaken.
3. The applicant must have obtained a satisfactory score on the appropriate entrance examination required for admission by the program or department to which admission is sought. The official score report must be submitted; a photocopy of the examinee's report is unacceptable. Unless otherwise stated under a specific program description, the required examination is the Graduate Record Examination Aptitude Test.
4. In accordance with Chapter 76 of the General Laws of the Commonwealth of Massachusetts, "No full-time student under thirty years of age or any full-time or part-time...graduate student in a health science who is in contact with patients shall...be registered at an institution of higher education except upon presentation of a medical certificate that such student has been immunized against measles, mumps, rubella, tetanus and diphtheria..." Graduate students will not be permitted to register unless they have provided evidence of immunization.

Departmental Requirements

The rules, regulations, and policies delineated by the Graduate School constitute only the minimum requirements for admission, retention, and graduation. Each department may have additional requirements mandated by the unique nature of the various programs. It is the responsibility of the graduate student to be aware of the minimum requirements of the Graduate School and, in addition, to fulfill the special requirements of the particular program in which she or he is enrolled.

Application Procedure

Application forms and materials may be obtained from the University of Lowell, Graduate School Office, Falmouth Hall 311, Lowell, MA 01854. A non-waivable and non-refundable application fee of $10 for Massachusetts residents ($25 for non-residents) must accompany the application. Each applicant must file the following documents: (1) a completed application form, (2) official transcripts of all undergraduate and graduate records, (3) three letters of recommendation written by individuals qualified to judge the ability of the applicant to carry on graduate work and research, (4) official scholastic test scores specified for various degree programs at the University (see individual departmental requirements), and (5) the official score report for the "Test of English as a Foreign Language" (TOEFL) for students from countries where English is not the national language. If the TOEFL bulletin cannot be obtained locally, students should write well in advance to: Test of English as a Foreign Language, Box 6151, Princeton, NJ 08541-6151, U.S.A.

All test scores must be official and sent directly by the testing agency. An applicant who has earned a graduate degree beyond the bachelor's degree from an accredited university may petition the department to which she or he is applying to waive the test requirements. If the department so requests, the Graduate School will waive the requirement.

Application Deadline

Although the University of Lowell Graduate School has a "rolling admissions" policy, a completed application, including all required documents, should be received on or before April 1 for a candidate who seeks admission for the subsequent summer or fall semester, and on or before November 1 for a candidate seeking admission for the subsequent spring semester. This early application will ensure that all materials are processed on time and that a student who wishes to apply for a teaching assistantship will be given due consideration. There is no guarantee that applications completed after these deadlines can be acted upon in time to permit registration in the desired session. Many programs will fill available openings several months before the beginning of the semester. A student who has been accepted to the Graduate School must attend within a year of acceptance or may, at the discretion of the Department, have to submit a new application. Application files will be kept for only two years from date of application.

Types of Admission

A student may be admitted to graduate study at the University of Lowell under one of the three classifications listed below.

1. Matriculated status: A student who has met all requirements for admission to a degree program and who has been recommended by the department in which he or she proposes to study as a degree candidate.

2. Matriculated with conditions: A student who has not fully met the requirements stipulated by the program may be admitted as a prospective candidate for a degree with specified conditions to be met. Such a student must have as an initial objective the satisfactory completion of all requirements for full matriculation. In order to change status to fully matriculated, a student must file, with supporting documentation, the appropriate Academic Petition form available from the Graduate School Office.
3. Non-Degree status: A student without advanced degree objectives may take courses in certain programs on the basis of non-degree status. A student who wishes to take courses as a non-degree student must submit a transcript indicating the conferral of a bachelor's degree. Such a student is not eligible to receive credit toward a degree unless she or he files a formal application and is then admitted as a matriculated student. Upon admission to matriculated status, the student must file an Academic Petition form to have any credits earned previously considered toward an advanced degree (See Transfer Credit, below).

Transfer Credit

The following are minimal guidelines for transfer of credit; individual departments are free to impose more stringent requirements. Only courses completed elsewhere within five years prior to the date of admission to a graduate degree program at the University of Lowell may be considered by the graduate faculty of the department for transfer in accordance with the following regulations.

1. A combined maximum total of 12 credits earned with a grade of B or better taken at the University of Lowell and/or another accredited institution may be transferred to a master's degree program (see individual programs for further restrictions, if any). A maximum of 24 credits may be transferred to a doctoral program.
2. An official transcript and description of the course(s) must be submitted with the written request.
3. The courses presented must be from an accredited U.S. or Canadian institution authorized to grant graduate degrees.
4. The courses presented for a master's degree must not have been used in earning another master's degree.
5. The courses presented must be appropriate to the degree program for which the applicant is applying.
6. The courses presented must be graduate level.
7. Transfer credit may not be granted for research seminars, clinical courses, practica, internships, or special projects.
8. Students who wish to transfer credit must file (within the first semester of matriculation) the Academic Petition form available from the Graduate School Office.

Requirements for Degree Conferral

Combined B.A./M.A.,B.S/ M.S. Degree Programs

In order to encourage outstanding undergraduate students to continue their studies toward an advanced degree, several departments have instituted a program of accelerated study which leads to combined bachelor's and master's degrees. Currently, such a program is offered in the following departments: Biological Sciences, Chemical and Energy Engineering, Civil Engineering, Criminal Justice, Electrical Engineering, Industrial Technology, Mathematics, Mechanical Engineering, Plastics Engineering, and Psychology, and in the program in Radiological Sciences.

To be eligible to enter one of these courses of study, the student must file a formal Graduate School application in the junior year in time for acceptance by the end of the late registration period at the beginning of his or her senior year. Graduate Record Examination scores are not required. Upon recommendation of the student's advisor, and with the approval of the departmental graduate admissions committee and the Dean of the Graduate School, the student may be admitted to graduate study with the condition that the bachelor's degree be obtained.

After the student receives a bachelor's degree, (at the end of the fourth year of study), if all course requirements have been met, she or he may be recommended for status as a fully-matriculated student by filing an Academic Petition. This should be done at or before the start of the fifth year.

Graduate or advanced undergraduate (400 level) courses taken during the senior year may be used for both the graduate and undergraduate degrees up to the amount indicated by each of the individual programs. The total number of credits used for the combined degree must, however, be greater than the minimum number of credits required to obtain an undergraduate degree. As an example, if the student's department requires 132 credits, and the University B.S. requirement is 120 credits, the student may, with approval, transfer up to 12 credits toward the master's degree.

As in the regular M.S. or M.A. program, the department may or may not require a thesis or additional courses, as specified by their rules and regulations. The student must also meet all departmental and Graduate School regulations for the master's degree.

A student accepted to one of these programs must continue directly after his or her senior year and must be registered as a full-time student during the master's degree work. An individual taking full advantage of the combined program ordinarily would be expected to finish the master's degree at the end of the fifth year of study. However, this will depend upon the student's course load and thesis work. The student may be eligible for financial assistance, i.e., fellowships and teaching assistantships, upon completion of the bachelor's degree, but this may delay completion of the program.

Master's Degree Requirements

Advising

An entering graduate student is assigned an academic advisor as soon as possible after arrival on campus. The advisor will:

1. help design and then approve the student's complete program leading to the master's degree;
2. recommend course credits from within and outside the University for transfer into the student's degree program;
3. monitor the student's progress toward the degree, which must be completed within a five-year time period in most programs. (See Time for Completion of Degree Requirements.)

General Requirements for the Master's Degree

To be recommended for a master's degree, a candidate must satisfy all requirements of the Graduate School and the specific requirements of the department in which he or she is enrolled. The requirements of the Graduate School are listed below, and the specific requirements established by the various departments may be found in the section describing the particular programs.

A candidate for the master's degree must complete the following within five years of matriculation in order to receive the degree.

1. A course of study designed by the department in which he or she is enrolled must be completed and approved by the Graduate School. The course of study must have a minimum of 30 credit hours of graduate study including, where applicable, a thesis or project in the student's chosen field.
2. A student must successfully pass an oral or written examination on his or her complete master's program if required by the department.
3. Satisfactory grades in all subjects offered for the degree must be earned. (See Retention Policy.)
4. All financial obligations, including tuition, fees and expenses, must be satisfied as evidenced by completion and submission of a signed Advanced Degree Clearance form to the Graduate School Office.

Research options for the Master's Degree

If required by the program, a student must complete a master's thesis or a master's project. The topic of the thesis or project must be of graduate level quality, and the proposal must be approved by the department in which the student is enrolled.

Project: The project will consist of a scholarly investigation, such as a review, report, synthesis or design in the student's field resulting in a written document. Usually, if a student chooses the project option, he or she is required to take additional course credits. Each project is awarded only three credits and is intended to be completed within the time limit of one semester. If the work for a project is not completed by the end of the semester, the instructor will give the student a grade of "I", which is to be treated the same as an incomplete for a regular course.

Thesis: The requirements for a thesis are much more extensive, including the completion of acceptable research and defense of it before a thesis committee. The completed thesis must conform to the format specified in the "Thesis Guide", which is available in the Graduate School Office, and the format must be approved by the Graduate School. The time required for completion may vary. Therefore, if a student has not completed the thesis by the end of the semester, but is making satisfactory progress, she or he is given the grade of "PR". If the student requires the use of university resources to complete the thesis, she or he must register for at least three credits of research for the following semester, even if the minimum number of credits required for the degree in her or his program have already been earned. However, if the student is not using university resources, but is in the process of writing the thesis, she or he may register for Continued Advisement for the semester/s until the work is completed. At that time, the grade of "S" will be awarded for the last semester in which the student is registered for thesis research.

Thesis Committee: As soon as a student has chosen an area of research, a Thesis Committee is selected by the student and his or her research advisor in accordance with the policy of the department. The Thesis Committee shall consist of at least three members, at least two of whom shall be from the student's major department. One member of the committee shall be the student's thesis advisor. An outside expert, such as the supervisor of a research project conducted at an industrial setting or a faculty member from another institution, may be a member of the committee, but that individual must possess academic qualifications which would qualify him or her to serve as a member of the University of Lowell faculty. The responsibilities of the Thesis Committee shall be to:

1. approve the research topic;
2. supervise the progress of the thesis;
3. arrange for the oral defense of the thesis;
4. report the completion of all thesis requirements to the department.

Thesis Preparation: Every graduate student who completes a thesis is required to

bear the cost of microfilming and binding two copies of the manuscript for the University's files in accordance with the following schedule, which is subject to change:

Binding fee (per copy) $15.00
Microfilming fee (master's) $35.00
Copyright fee (optional) $25.00

Doctoral Requirements

The University of Lowell offers the Ph.D. in Chemistry and Physics, the D.Sc. in Computer Science and Work Environment, the D. Eng. in Electrical, Mechanical and Plastics Engineering, and the Ed.D. in Education. Requirements for each program vary considerably, but those which apply to all programs are listed below. Applicants should refer to the specific program for additional requirements. In all cases, it is possible to obtain the master's degree in the discipline if a student has completed the requirements and decides not to pursue the doctorate. Full-time faculty of the University of Lowell are not eligible to earn a doctorate from this University during their employment.

Advising

An entering doctoral student is assigned an academic advisor as soon as possible after arrival on campus. This advisor is selected by the Graduate Coordinator of the department in which the student is enrolled. The advisor will:

1. monitor and approve the student's program of study leading to the doctorate;
2. recommend to the coordinator of the program course credits from within and outside the University for transfer into the student's doctoral program;
3. approve the procedure by which the student intends to satisfy the language requirement (if any);
4. advise the student in regard to the qualifying examination/s;
5. meet regularly with the student to determine his or her progress toward the degree and help solve any problems that may arise; and
6. report on the student's progress to the Graduate Coordinator of the program.

Residence Requirement

The equivalent of at least one academic year of full-time graduate work must be spent at the University. The requirement for a year in residence may be satisfied only by the student's physical presence on campus for two consecutive semesters. This may be either a fall-spring sequence, or a spring-fall sequence. It cannot be satisfied by a summer session and a semester of the regular school year.

Language Requirement

Individual departments will determine the number of foreign or computer languages and the level of competency required of doctoral students, if any.

Doctoral Research

In addition to the other requirements of the Graduate School, a candidate for a doctoral degree must complete an acceptable dissertation. The dissertation must satisfy the following criteria: 1) it should demonstrate the candidate's intellectual competence and maturity in the field of concentration; 2) it should make an original and valid contribution to knowledge; and 3) it should be an individual achievement and the product of independent research. Although doctoral dissertations may result from a project involving collaboration of several scholars, the individual contribution of each doctoral candidate must be substantial, clearly identifiable, and separately presented. The dissertation in its completed form will be judged upon the ability of the candidate to review and make critical use of the literature; to formulate a problem, plan a method of attack, and work systematically toward a solution; and to summarize the material or data and draw conclusions from them. The writing should be of publishable quality.

Dissertation Committee

After a student has chosen an area of research and a research supervisor, a Dissertation Committee is selected by the student and his or her research advisor in accordance with the policy of the department. The Dissertation Committee shall consist of at least three members, one of whom is the research supervisor and at least two of whom shall be from the student's major department. An outside expert from industry or another university may be a member of the committee, but that individual must possess academic qualifications which would qualify him or her to serve as a member of the University of Lowell faculty. The responsibilities of the Dissertation Committee shall be to:

1. approve the research topic;
2 supervise the progress of the dissertation;
3. arrange for the oral defense of the dissertation;
4. report the fulfillment of all dissertation requirements to the department.

Dissertation Credits

A graduate student who has completed the minimum number of research credits required for the degree, but who has not yet completed his or her dissertation research must register for at least three credits of research each semester. (Note: International students on an F-1 visa must be registered for a minimum of nine credits each semester.) Graduate students who have completed all the requirements except the writing and defense of the dissertation and do not need to use university resources must register for Continued Advisement (00.601.201) and pay a registration fee each semester until they graduate.

Manuscript Preparation

Every graduate student who completes a dissertation is required to bear the cost of microfilming and binding two copies of the manuscript for the University's files in accordance with the following schedule, which is subject to change:

Binding fee (per copy) $15.00
Microfilming fee for doctorate $45.00
Copyright fee (optional) $25.00

Doctoral Degree Requirements

The doctoral degree is conferred upon graduate students who have met the requirements listed below.

1. The student must successfully complete the graduate courses in the major field and the number of credits required by the particular program.
2. If indicated, the language requirement specified by the major department must be completed satisfactorily.
3. A qualifying examination, oral and/or written, conducted by the major department, must be passed before any work is begun on the dissertation. If the student fails the qualifying examination she or he may, at the discretion of the department, be permitted a second and final opportunity. At this point, having completed steps 1 through 3, the student is admitted to candidacy for the doctorate.
4. The residence requirement must be satisfied.
5. A dissertation based upon the results of original research which is satisfactory to the Dissertation Comittee of the major department must be completed.
6. A final oral dissertation defense conducted by the Dissertation Committee, based primarily upon, but not necessarily limited to, the contents of the candidate's dissertation must be passed. The examination cannot be scheduled until all members of the Dissertation Committee have had seven working days in which to read the dissertation. The oral examination is to be conducted by the Dissertation Committee, whose membership may be augmented by the non-voting faculty and representatives of the Graduate School. In order to pass the defense, the candidate may not receive more than one dissenting vote from the members of the Dissertation Committee.

7. All financial obligations (tuition, fees, and expenses) must be satisfied as evidenced by the completion and submission of an Advanced Degree Clearance form to the Graduate School Office.

General Regulations

Continuous Registration of Graduate Students

In order to maintain a continuity of registration, a matriculated student must register each fall and spring until the program of studies is complete and the degree has been earned. A graduate student who plans to receive an advanced degree in October, however, must register during the previous summer session in order to maintain continuous matriculation.

If for any reason a student is not registered for a course (because of leave of absence or because all course work except the thesis or dissertation is complete), the student must register for 00.601.201 (Continued Advisement) in order to maintain continuous matriculation. A master's degree candidate may register for 00.601 for not more than one academic year, a doctoral candidate for not more than three academic years. Continued Advisement does not entitle a student to any use of university facilities or resources, but only maintains an active record and provides for appropriate mailings. A student working on thesis or dissertation research who must use the university libraries, laboratories, or other resources must register for additional research, for at least three credits.

An international student on an F-1 visa may not register for Continued Advisement and must register as a full-time student (9 credits) each semester until the degree requirements are completed.

A student who fails to maintain continuous matriculation loses the status of a degree candidate and must reapply to the Graduate School for readmission and for renewal of candidacy.

Time Limit for Degree Completion

A graduate degree, at either the master's or doctoral level, implies a degree of mastery of a discipline. A well designed curriculum is not a mere collection of courses that add up to a set number of credits. It is, rather, a coherent selection of courses with an overall educational impact that is larger than the sum of its parts. However, this coherence is lost if the program is completed over a long time span. Therefore, degree requirements for the master's degree must be completed within a five-year period, except for those programs requiring 45 or more credits, in which case the time limit is six years. The doctoral degree must be completed within an eight-year period beginning the semester of admission as fully matriculated or matriculated with conditions. A student may obtain an extension of one year by academic petition signed by his or her coordinator, department chair and the Dean of the Graduate School. In exceptional cases, an additional extension may be granted by the Graduate Academic Policy Committee, upon presentation of the Academic Petition, a letter of explanation accompanied by a schedule for completion, and a letter from the student's coordinator or thesis advisor concurring with the request.

Course Numbering System

400-499 These are undergraduate courses usually designed for juniors or seniors; no more than six credits may be taken for graduate credit, with the permission of the advisor.

500-599 These courses are for graduate credit, but may be taken by advanced undergraduates with the advisor's permission.

600-799 These are graduate courses which are open to graduate students only.

Credit designation is listed opposite the number and title of each course and indicates whether the course is a lecture or laboratory, e.g., (3-3)4, indicates a course with lecture for three hours, laboratory for three hours, and for which four credits is awarded.

Course Listing on the Graduate Transcript

All graduate courses, including repeated courses, for which a student registers are listed on the transcript and used to calculate the student's grade point average, whether or not they are taken to fulfill degree requirements or are in the student's field of concentration. In addition, undergraduate courses which a student is taking to fulfill pre-requisite requirements before or during matriculation in a graduate program or for personal enrichment will also be listed. A departmental graduate committee may recommend to the Dean of the Graduate School that this requirement be modified.

Academic Grades

The grading system uses grades A, AB, B, BC, C and F with the numerical equivalents of 4.0, 3.5, 3.0, 2.5, 2.0 and 0. The following special grades are also used: I (Incomplete), S (Satisfactory, B or better), U (Unsatisfactory), AU (Audit), W (Withdrawal from a course or from the University), X (Withdrawal because of illness or personal emergency), Y (Administrative dismissal), Q (Never attended but did not withdraw), PR (In Progress for courses in Thesis or Dissertation), and NC (No Credit for courses in Thesis or Dissertation where no progress has been made). A student registering for research will do so in 3-credit multiples each semester up to a total number recommended, and a student registering for seminar will register for 1-credit multiples each semester. No graduate degree will be awarded to a student whose cumulative average for course work is below 3.0. Some programs may require a higher grade point average for graduation. The cumulative grade point average is computed from all graduate level courses taken for a grade at the University of Lowell and from any undergraduate courses taken at the University of Lowell which have been approved by Academic Petition to be transferred into the graduate program, unless a specific request is received from the student's departmental graduate committee to add or omit specific courses to or from the average. If a course is repeated, the transcript will list both attempts and both grades will be used in calculating the grade point average.

Incomplete

If, because of circumstances beyond control, a student is unable to meet all the requirements of the course by the end of that semester, the grade of I (Incomplete) may be given. The award of this grade requires an understanding between the instructor and the student concerning the completion of course work. The maximum time limit for submission of all course work necessary for removal of an Incomplete is the last day of classes of the next semester following the semester (or summer session) in which the grade was received. After that time, an unchanged grade of Incomplete is changed automatically to F. An extension of the time limit is possible but must be approved, prior to the expiration date stated above, by the instructor and the Dean of the College through which the course is offered. Written approval indicating the new time limit must be filed with the Dean of the Graduate School.

Audit

A graduate student may, upon approval of the advisor and the instructor, register for a course on an audit basis, but must pay the full amount of tuition and fees. An audit student is not required to take tests or the final examination. A change in registration from audit to credit must be effected during the add/drop period. Under no circumstances can a course taken for audit be given credit at a later date. A student may change status from credit to audit until the last day in the semester on which withdrawal is permitted.

Withdrawal

A student finding it necessary to withdraw from a course must do so within the time specified in the academic calendar. This is usually at the end of nine-tenths of the course duration, or at the end of the sixth week for a seven-week course. The student's permanent record will indicate a grade of W for the course(s) from which he or she has withdrawn

unless the withdrawal has taken place within the first 10 class days of the semester, during which time no record will be kept.

A student who wishes to withdraw from the University must obtain the appropriate signatures on the withdrawal clearance form and submit it to the Graduate School. This procedure ensures that the student's academic and financial obligations are cleared before leaving the University. For a student officially withdrawing from the University, the permanent record will indicate a grade of W. If the student fails to follow the official withdrawal procedure and does not withdraw in good standing, official transcripts of the student's academic record will not be issued and the student will not be permitted readmission to the Graduate School except under extenuating circumstances. A student's file will remain active up to two years after withdrawal. At any time during this period, a student may request readmission by writing to the Graduate School. After two years, a student must file a new application in order to be readmitted to the Graduate School.

In Progress

For courses in thesis or dissertation research, the student is assigned the grade PR (In Progress) or NC (when no progress has been made). This grade will be indicated on the student's record each semester until the thesis or dissertation is completed. During the semester when the work is completed, the grade of S (Satisfactory) or U (Unsatisfactory) will be given.

Graduate Credit for Undergraduate Courses

Courses at the 400 level are designed for seniors but under certain circumstances may be taken by graduate students for graduate credit. At the time of registration the student who wishes to do so is required to file a Special Petition form obtainable in the Graduate School. A maximum of 6 credits of 400 level courses may be used for credit toward the graduate degree. If a graduate student takes certain undergraduate courses to make up background deficiencies, the course credit hours are not used as part of the graduate degree program, but will appear on the graduate transcript.

Undergraduate Credit for Graduate Courses

A qualified junior or senior may take a course at the 500 level for undergraduate credit in accordance with the policy and procedures of the department or college in which the course is offered. The grade received in any such course is used in calculating the undergraduate's cumulative grade point index. Such a student may not earn graduate credit until he or she has completed all requirements for the bachelor's degree.

Changes in Registration

Courses may be added, dropped, or changed from audit to credit by completing the appropriate add/drop forms and obtaining the permission of the course instructor and the student's advisor. This may be done during the first 10 academic days of the semester. Courses dropped will not appear on the student's permanent record. After this period, no new courses may be added and no course may be changed from audit to credit. A student wishing to drop courses may do so by the date indicated on the Graduate School Academic Calendar, and the grade for these courses will appear as W on the student's record. All changes in registration must be brought by the student to the Graduate School Office for processing or they will not appear on the student's record.

Change of Major

In order to change the major or area of concentration, the student must submit to the Graduate School an Academic Petition signed by the coordinator and department chairperson of the new and old major. This petition should include the date of acceptance of the student to the new program, which cannot take place until the student has been in the original department for at least one semester, and should indicate the courses and the total number of credits that may be transferred to the student's new degree program. A new application fee will be charged for this transaction.

Transfer to Another Program

A student must file an Academic Petition to request a change of program within a given department.

Transcripts

In order to obtain a transcript, a student must submit his or her name, major and year attended or graduated to the Registrar's Office through a written request by mail or by filling out the appropriate forms available in the Registrar's Office. Transcripts given directly to students do not carry the University seal and are not official. The seal is attached when the transcript is mailed directly from the University to the receiving party.

Retention Policy

No more than 6 credits of C and/or BC may be counted toward the master's degree; no more than 9 credits of the same grades may be counted toward the doctorate. No advanced degree will be awarded any student whose overall cumulative grade point average falls below 3.0. A student earning one C or BC will be reviewed by his or her advisor and the coordinator of the appropriate program. A student earning two C's or BC's will be reviewed by the Graduate Committee of the appropriate department for such action as a warning, probation, loss of degree candidacy, etc. A student receiving more than two C's and/or BC's or any grade lower than a C will be reviewed by the Graduate Committee of the appropriate department for such action as dismissal, probation, loss of degree candidacy, imposition of additional requirements, etc. Action on such students is subject to the approval of the dean of the appropriate college. The Dean of the Graduate School may at any time examine the performance of any student not living up to the academic standard expected of graduate students and recommend to the appropriate graduate committee a course of action to remedy the situation. A graduate student dropped for academic reasons may appeal to the graduate committee of the appropriate department or college for review of the decision.

Statement on Academic Honesty

It is the expressed policy of the University of Lowell that graduate academic life related to the University will be conducted in an honest and uncompromising manner by the graduate students and faculty. Apparent and all alleged breaches of this policy will be dealt with by the Graduate Academic Policy Committee in accordance with the procedure delineated in the graduate appeals process.

Definition of Academic Dishonesty

The following definitions are provided for the information of all students and constitute official notice of prohibited academic practice and behavior.

Cheating is defined as (1) misrepresenting academic work which has been done by another as one's own efforts - whether such misrepresentation has been accomplished with or without the permission of the other individual; (2) utilization of prohibited assistance (whether in the nature of a person or a resource) in the performance of assignments and examinations; (3) copying of another person's work or the giving or receiving of information or answers by any means of communication during an examination; (4) utilization of the services of a commercial term paper company; and (5) the unauthorized or fraudulent acquisition and or use of another's academic property.

Plagiarism is defined as (1) direct quotation or word-for-word copying of all or part of the work of another without identification or acknowledgement of the quoted work; (2) extensive use of acknowledged quotation from the work of others which is joined together by a few words or lines of one's own text; and (3) an unacknowledged abbreviated

restatement of someone else's analysis or conclusion, however skillfully paraphrased.

University Appeals Process Regarding Academic Issues of Graduate Students

The underlying purpose of the University appeals procedure is to guarantee due process and to protect the rights of both students and faculty in graduate programs. The following procedure provides a mechanism for formal adjudication of any academic issues which may arise. Responsibility for initiation of each of the steps belongs to the appellant.

Step 1. If an informal discussion between the student and the instructor does not resolve the issue, the resolution of an academic appeal of a student should begin within the department. The first step in the resolution of a problem or disagreement should be an informal discussion between the instructor, the student, and his/her faculty advisor or the coordinator of the program.

Step 2. If the matter cannot be resolved after such a discussion, a formal appeal, in writing, should be presented by the student to the chairperson of the department, who should appoint an appropriate committee composed of graduate faculty members in the department. Within seven working days, this committee shall convene and discuss the appeal with the student. The student may be accompanied by his or her advisor or a faculty representative during the discussion of the appeal. The committee, by a majority vote, shall render a decision within five working days and notify the appropriate parties in writing with the rationale for the decision included in the notification.

Step 3. If the decision is not satisfactory to all parties, the appeal may be forwarded to a college committee composed of area coordinators of all graduate programs within the college or a suitable committee of graduate faculty, in the case of a small college, to be appointed and chaired by the Dean, or in his/her absence, the Assistant Dean. Within seven working days the committtee shall convene and discuss the appeal with the student. At this level the student may request to be present at the committee meetings, that discussions or proceedings be tape recorded, and that a transcript be prepared from the tape. The request for recording must be made at the time the appeal is made to the college committee. The committee shall render a decision within five working days and notify the appropriate parties with the rationale for the decision included in the notification.

Step 4. If the decision is not satisfactory to all parties, the appeal may be forwarded to the Graduate Academic Policy Committee. The committee shall convene within 10 working days and discuss the appeal with the student and faculty advisor or representative. A request for recording and preparing a transcript of the discussions with the student present may be made at the time of appeal. The committee shall render a written decision within five working days and notify the appropriate parties. The decision of the Graduate Academic Policy Committee shall be final, and the information accumulated during the appeal procedure shall be forwarded to the Dean of the Graduate School to be kept on file. If any decision involving the awarding of a degree is made and the official deadline for graduation exercises has passed during the appeal, the degree date will reflect the initiation of the appeal.

University Disciplinary Procedures for Graduate Students

The underlying purpose of University disciplinary procedures is educational. Such procedures accordingly seek to promote the achievement of self-discipline and self-direction on the part of the student by fostering personal responsibility and accountability. In the administration of these procedures, the University recognizes the legitimate concern of the student body, the faculty, and the administration and is committed to a proper balance between protection for the individual and the academic community. In the imposition of disciplinary penalties, the University makes every effort to avoid dual punishment of an offender for the same wrongful act and therefore refrains from disciplinary action when sufficient disposition of an offense has been made by a court of law. Unlawful acts and acts of misconduct which are committed off campus are not the responsibility of the University and are not subject to adjudication by University procedures.

The Role of the Dean of the Graduate School

All complaints concerning student misconduct or charges concerning violation of administrative requirements of the University must be forwarded in writing to the Dean of the Graduate School who, within a reasonable time thereafter, shall provide the student with the name of the complainant, a copy of the charges filed, and statement of hearing procedures and individual rights of due process. Within five academic days of this notification, the Dean of the Graduate School shall schedule a personal interview with the student, at which time the student may explain the circumstances of the complaint or charge and/or may affirm the charges or complaint as filed, may call witnesses on his or her behalf, and may confront and question those who appear to give testimony. Within a week of this interview, the Dean of the Graduate School shall render a decision concerning the complaint or charge filed and shall forward a copy of his decision to the student and complainant by certified or registered letter, return receipt requested. In the event that the Dean has specified a sanction, his letter shall notify the student of his or her right to appeal the decision to a Board of Appeals and to be represented and/or assisted by a faculty adviser in making such an appeal.

The Dean of the Graduate School shall have authority to impose a sanction without recourse by the student to subsequent hearings if the student has failed to report for a personal interview as scheduled and has not been excused from reporting for good and sufficient reason. If a student against whom a sanction has been imposed makes no appeal to a Board of Appeals, the punishment determined by the Dean of the Graduate School shall be implemented within 10 days. Pending action on an appeal of sanction imposed by the Dean of the Graduate School, the status of a student shall not be altered and his or her right to be present on campus and to attend classes shall not be suspended unless, in the opinion of the Dean of the Graduate School and the Vice-President for University Life, failure to implement such sanction may reasonably pose a threat to the safety of persons or the protection of University property.

The Composition and Role of the Board of Appeals

The Board of Appeals shall consist of two graduate faculty members appointed by the Chairperson of the Graduate Faculty, two administration members appointed by the Vice President for University Life, and three graduate student members appointed by majority vote of the Graduate Student Association. An alternate shall be appointed respectively by the Chairperson of the Graduate Faculty, the Vice-President for University Life, and the Graduate Student Association for each regular member designated. Upon written notification to the Board at least two days prior to a scheduled hearing, the student defendant or the Dean of the Graduate School each has the right to remove, without cause, one regular member of the Board and to replace such member with his or her designated alternate. The Board shall elect a person from among its members who shall conduct the hearing and who shall assume reponsibility for assuring an accurate record of the hearing.

An official record of the hearing, including a record of testimony, shall be made by a duly appointed stenographer or by tape recorder. The transcript or tape recording shall be for the use of the Board only, and upon the conclusion of the hearing it shall be deposited with the Vice-President for University Life,

who shall subsequently release this record only upon the direction of the President of the University or upon the order of a court of competent jurisdiction. Upon the student's graduation or withdrawal from the University, a copy of the offical record of the student's hearing may be released to the student when such release has been approved by the Vice-President for University Life.

The Board of Apeals shall receive a written charge from the Dean of the Graduate School which provides the name of the accused student and the specific allegation of student misconduct. A copy of such charge shall be conveyed to the student by the Board, together with a notice of time and place of official hearing before the Board. The student may be assisted in his or her defense by a graduate faculty adviser and/or legal counsel of his or her choice, may present evidence, and may call witnesses in his or her defense. Hearings before the Board of Appeals shall be private unless the student has filed a written request for a public hearing with the Board at least two days prior to the scheduled hearing date.

Attendance at Hearings of the Board of Appeals

The following individuals shall have a right to be in attendance at a hearing of the Board of Appeals: the Dean of the Graduate School, the student defendant, the student's graduate faculty advisor, and/or legal counsel, the complainant and the legal counsel of the Board of Trustees. Individuals other than those enumerated above who have a direct interest in the proceedings may be permitted to attend at the discretion of the Board. The Board may revoke such permission at any time during the course of a hearing. A decision to permit an individual's attendance or to revoke such permission shall require a five/seven majority vote of the Board.

Admissibility of Evidence

Decisions of the Board of Appeals shall be based solely upon evidence which has been introduced during official Board hearings. Improperly acquired evidence shall not be admitted before the Board. In any proceeding, the admissibility of evidence shall be governed by the Rules of Evidence which are specified by Chapter 30 A of the General Laws (State Administrative Procedure Act) concerning adjudication. Information pertaining to the defendant's academic standing or to his or her previous record of offenses shall be introduced in hearing only if the Board deems such information to be relevant. Each witness testifying during a Board hearing shall be called into the hearing room at the time he or she is to testify and shall leave the hearing room immediately after providing testimony. Members of the Board, the student defendant, the defendant's graduate faculty advisor, and the Dean of the Graduate School may question any witness concerning his or her testimony.

Powers of the Board of Appeals

The legal counsel for the Board of Trustees shall be the legal adviser to the Board of Appeals. By an affirmative vote of five/seven, the Board of Appeals may affirm, reverse, increase, or decrease a sanction which has been imposed by the Dean of the Graduate School. Upon the conclusion of each hearing and within 10 working days the Board shall forward a written statement of its decision, signed by all Board members, to the President of the University, the student defendant, the complainant, and the Dean of the Graduate School. All decisions of the Board of Appeals shall be implemented on the third academic day (including summer sessions) following the date of Board notification to the student defendant unless the Dean of the Graduate School or the student defendant notifies the Board in writing of his or her decision to appeal the Board's decision to the President of the University.

Appeal to the President of the University

An appeal to the President of the University may be initiated by the Dean of the Graduate School or the student defendant and must be made in writing to the Vice-President for University Life within two academic days following notification by the Board of Appeals. The President's review shall be based on the complaint, the decision of the Dean of the Graduate School, the record of the hearing, and the decision of the Board of Appeals. The decision of the President shall be implemented within 10 days following the date of presidential notification to the student defendant unless the student defendant notifies the President in writing of his or her decision to appeal the President's decision to the Student Affairs Committee of the Board of Trustees. In the event that the President alters the decision rendered by the Board of Appeals, he shall provide a written statement of his decision, together with his reasons, to the Board of Appeals.

Appeal to the Board of Trustees

A student defendant has a right to appeal the decision of the President to the Committee on Faculty, Academic and Student Affairs and Long-range Planning of the Board of Trustees. This appeal must be made in writing to the Vice-President for University Life within two academic days following the date of presidential notification to the student defendant. All decisions of the Student Affairs Committee of the Board of Trustees are final and shall be implemented within 10 days.

Description of Courses

College of Arts & Sciences

Co-Dean: Peter R. Blewett, A.B. Northeastern University, A.M., Ph.D., Boston College; Arthur C. Watterson, Jr., B.S. Geneva College, Ph.D. Brown University.
Assistant Deans: Richard Derry, A.B. Holy Cross College, A.M. Boston College; F. Raymond Hardy, B.S., M.S. Lowell Technological Institute.

The College of Arts & Sciences offers 26 programs of graduate study including Master of Arts, Master of Science, Doctor of Science, and Doctor of Philosophy Degrees in a variety of fields. These degree programs are part of the University's commitment to develop regional and national economies by providing state-of-the-art educational programs beyond the bachelor's degree. A wide range of on-going research and project opportunities exist within the various degree programs, and interdisciplinary study is emphasized. Graduates of these programs are heavily recruited both regionally and nationally by industry and governmental agencies.

Master of Arts Degrees (M.A.)

Community Social Psychology
Criminal Justice

Master of Science Degrees (M.S.)

Biological Science
  Biotechnology Option
Chemistry
Computer Science
Mathematics
  Applied Mathematics Option
  Mathematics for Teachers Option
  Statistics Option
  Scientific Computing Option
Physics
Polymer Science
Radiological Sciences and Protection

Doctor of Philosophy Degrees (Ph.D.)

Chemistry
  Biochemistry Option
  Environmental Studies Option
Polymer Science/Plastics Engineering Option
Physics
  Applied Mechanics Option
  Energy Engineering Option
  Optics Option
Polymer Science
Radiological Sciences

Doctor of Science (Sc.D.)

Computer Science
Work Environment

Department of Criminal Justice

Department Chairperson: Joseph W. Lipchitz, Professor; B.A., M.A. University of Massachusetts; Ph.D. Case Western University.
Graduate Coordinator: James M. Byrne, Associate Professor; B.A. University of Massachusetts; M.A., Ph.D., Rutgers University.
Faculty: Eva S. Buzawa, Associate Professor; B.A., University of Rochester; M.S., Ph.D., Michigan State University; June M. Gonsalves, Associate Professor; B.A., Northeastern University; J.D. Northeastern University; Gerald T. Hotaling, Associate Professor; B.A., University of Delaware; M.A., Ph.D., University of New Hampshire; Alan J. Lincoln, Professor; B.S., Michigan State University; M.S., M.A., Ph.D., University of Massachusetts; Renné G. Kasinsky, Associate Professor; B.A., M.A., Ph.D., University of California, Berkeley; Larry J. Siegel, Professor; B.A., City College of New York, M.A., Ph.D. State University of New York, Albany

Master of Arts in Criminal Justice

Program Objectives

The Master of Arts in Criminal Justice program is designed to meet the diverse needs of criminal justice professionals in the Commonwealth of Massachusetts. Courses are offered in three separate subject areas: (1) technology and research in criminal justice, (2) criminal justice management and planning, and (3) crime and the community. The program has been designed to accomplish a number of important objectives:

1. To meet the needs of the Commonwealth of Massachusetts for criminal justice graduates to fill positions in teaching, research, and management in criminal justice agencies.
2. To prepare students for leadership positions in the administration of criminal justice agencies at the local, state and federal levels as well as in the private sector.
3. To assist students in applying theory and research to real-world problems in criminal justice.
4. To prepare students to conduct quality research on crime measurement, causation, impact, and the effect of state and local policies on crime.
5. To provide students with knowledge about methods of crime control in public and private settings.
6. To provide students with a thorough knowledge of the developmentof current issues in criminal justice and the relationship of criminal justice to other social and behavioral sciences.
7. To train students in the application of computer technology to decision-making in the criminal justice system.
8. To prepare students to apply skills in research, technology, management and intervention to the unique needs of their communities.

Expected Academic/ Professional/Occupational Results

It is anticipated that the program will serve predominately four types of students:

1. Those seeking a terminal master's degree as a prerequisite for entry into the criminal justice field.
2. Those currently in service in the criminal justice system who seek to broaden their skills and obtain job-related knowledge and expertise.
3. Those currently in the criminal justice system seeking to specialize and/or work in some other area of the system.
4. Those currently in the system or pre-service who wish to obtain the training and expertise necessary to meet the growing need for teaching criminal justice at the community college level.

In addition, the program will meet the needs of students considering preparation for eventual doctoral work in criminal justice or related fields.

Admission Requirements

Applicants should have the ability to pursue graduate education, as demonstrated by:

1. Graduation from an accredited four-year institution.
2. Minimum undergraduate grade point average of 2.8 or higher.
3. Acceptable scores on the Graduate Record Examination Aptitude Test.
4. Three letters of reference from individuals familiar with the educational and/or professional performance of the applicant.
5. Two copies of a complete and official transcript from each undergraduate and graduate institution attended.
6. An interview may be requested by the Graduate Admissions Committee.

Students with a bachelor's degree from an accredited program who have a grade point average between 2.5 and 2.79 may, with the permission of the Graduate Coordinator, take no more than two courses as non-degree students. These non-degree students are allowed to take 44-501 Foundations of Criminal Justice Scholarship and 44-570 Administration of Justice only. If they successfully complete these two courses with a grade of "B" or better, they may then make formal application to the program, submitting all required credentials. The Graduate Committee of the Criminal Justice Department will then review all relevant information and make a decision regarding admission to the program.

Students may be admitted in one of three categories:

1. Matriculated student - a fully accepted degree candidate who meets all criteria.
2. Matriculated with conditions - from time to time a student may be accepted conditionally into the program. To become a fully matriculated student, the student must receive at least a 3.0 grade point average in nine credit hours of criminal justice graduate level courses, while also completing conditions established by the entrance committee.
3. Non-degree. When space permits, qualified students will be allowed to enroll in selected courses. Subsequent application to the program will permit transfer into the program of no more than six credits of course work with grades of B or better.

Degree Requirements

All students will complete a minimum of 36 credits for the Master of Arts degree. Included in the 36 credit requirement is a core course sequence of 15 credits. The core consists of:

44-501 Foundations of Criminal Justice Scholarship 3 cr.
44-503 Administration of Justice 3 cr.
44-521 Criminological Theory 3 cr.
44-580 Quantitative Analysis in Criminal Justice 3 cr.
44-590 Research Methods in Criminal Justice 3 cr.

In addition, all students must complete one of the following:

44-734 Master's Project 3 cr.
or
44-743 Thesis Research 6 cr.

Master's Thesis Requirements

All students must successfully complete either a 6 credit thesis or a 3 credit project. Those students undertaking a project will be required to take an additional 3 credit approved graduate course.

Effective January 1990, those students already matriculated in the program who did not choose the thesis option will be allowed a choice of either taking the comprehensive examinations or selecting the project option.

Degree Program

During the first year of full-time study, students are expected to complete four of the five core courses. The decision to complete either a thesis or a master's project will be made before the end of the first academic year. The consideration of possible research topics will be made during the first year. During the second year of full time study, students will enroll in the option of their choice. Selected specialty courses will be taken during the second or subsequent year.

With the approval of the academic advisor, students may select up to nine credits of graduate level courses in other programs at the university. Courses may be selected from Education, Computer Science, or Management. Two courses in Community Social Psychology are currently cross-listed with Criminal Justice and may be applied as courses within the major: Community Dynamics: Intervention and Change, and Program Evaluation.

Students will be assigned an academic advisor when entering the program. Individual programs will be developed consistent with the student's needs and goals. Students will be required to maintain a 3.0 cumulative average. If a student should receive a grade of BC or C, the academic advisor will meet with the student to discuss methods of improving performance.

No more than six credits of C or BC my be counted toward the degree. If a student should receive a second C or BC, there will be a review by the Graduate Committee for such actions as a warning, probation, or loss of degree candidacy. Such action will be subject to the approval of the College Dean.

Any student whose credit load is less than full time will meet at least once a semester with his/her advisor to discuss and review progress toward the degree. All requirements for the degree must be completed within five years of the time the student was first admitted as a matriculated student.

Master's Thesis

The thesis will be completed under the direction of a mutually acceptable thesis advisor. The thesis proposal will be developed in conjunction with the thesis seminar and must be approved by the thesis advisor and Graduate Coordinator. An approved copy of the proposal will be filed with the Graduate Coordinator. The thesis will represent the student's ability to formulate, carry out, and present a significant research project. A "defense of thesis" will be conducted before a panel including the thesis advisor (chair), a committee member chosen by the student and approved by the department, and a third member selected by the Graduate Coordinator.

Course of Study

Once the required core courses (see*) are completed, students are free to choose the remaining courses in their program of study. There are three possible concentrations: (1) technology and research, (2) management and planning, and (3) crime and the community. Students should meet with their advisor to develop an individualized course of study that best meets their interests and needs.

Area 1: Technology and Research

***44-501 Foundation of Criminal Justice Scholarship** (3-0)3
This course is designed to improve the technical writing skills of criminal justice graduate students. Emphasis will be on the fundamentals of written (and oral) report preparation.

***44-590 Research Methods in Criminal Justice** (3-0)3
Students are introduced to the essential elements of criminal justice research, including criminal justice data sources, conceptualization and measurement, the use of experimental and quasi-experimental designs, survey research, document studies, and ethnographies. The use of computers as a research tool will be covered.

44-591 Research Methods in Criminal Justice II (3-0)3
Specific practice in the definition, design and execution of a research project and an analysis of the impact of contemporary criminal justice research on policy development. Computer applications will be examined.

44-530 Technology and the Law (3-0)3
The response of the legal system to technological changes in science, engineering and medicine as they affect both the law and the criminal justice professional.

***44-580 Quantitative Analysis in Criminal Justice** (3-0)3
Students are introduced to a variety of statistical techniques applicable to problem solving in the criminal justice system. This course is designed for both producers and consumers of criminal justice research.

44-592 Criminal Justice Information Systems (3-0)3
A comprehensive examination of the development, utilization and evaluation of computer-based information systems in criminal justice agencies. Focus on the development of management information systems.

44-593 Computer Crime and Security (3-0)3
Examination of the causes and consequences of computer crime, as well as the criminal justice system's response to the problem.

44-680 Special Topics in Technology and Research (3-0)3
Possible topics will include models of decision making, social indicators, comparative research in criminal justice, prediction methods, and advanced statistics for criminal justice.

44-690 Advanced Quantitative Analysis (3-0)3
The application of advanced statistical techniques to research problems in criminal justice. A variety of multivariate statistical techniques will be examined, including OLS regression, discriminant analysis, and LOGIT and PROBIT models.

44-691 Directed Study in Criminal Justice (3-0)3
This course is designed as an independent study of a subject not offered in the standard curriculum.

44-692 Computer Applications in Criminal Justice (3-0)3
Application of computer technology to decision-making in the criminal justice system. A variety of computer applications are presented including computer mapping, forecasting techniques, simulations and modeling.

44-735 Master's Project (3-0)3
This course will require the production of a significant research or analytical study under the immediate direction of a faculty member and under the general approval of a faculty committee of no fewer than two members. Normally such a project will be in cooperation wilth some professional criminal justice agency.

44-790 Thesis Seminar (3-0)3
For graduate students in the early stages of thesis planning, this will focus on the mechanics and details of thesis work. In the second semester students will continue to research and prepare the thesis itself.

Area II: Criminal Justice Management and Planning

***44-503 Adminstration of Justice** (3-0)3
An examination of the administration of federal, state and local criminal justice agencies in the United States, including the key concepts in criminal law and procedure.

44-511 Planning and Program Development (3-0)3
Examination of the techniques of planning and program development in criminal justice agencies. Introduction to the key steps in the planning process, and the program design.

44-531 Law of Administrative Procedures (3-0)3
General principles of administrative law, labor law, application of principles, law enforcement policy making, and implementation of constitutional safeguards. Examination of police unions and political activity.

44-550 Issues in Correctional Administration (3-0)3
Specific analysis of the management of correctional institutions, including custody, classification, reception, programming, release, staffing, scheduling, collective bargaining, prisoners' rights, and other related issues.

44.570 Criminal Justice Management and Planning (3-0)3
A range of criminal justice management issues are addressed, including organizational structure, purpose, rewards and relationships, leadership and management styles, and the development of effective change strategies by criminal justice agencies. The complex role of the criminal justice manager in both the adult and juvenile justice system is emphasized.

44-572 Personnel Administration (3-0)3
Explores current controversies in areas of significant change in personnel administration of criminal justice agencies. Includes collective bargaining, professionalism, motivation, training, productivity, and accountability.

44-573 Public Policy and the Criminal Justice System (3-0)3
Analysis of the interrelationship of criminal justice system components and the political setting surrounding the formulation and administration of public policies for crime control.

44-681 Special Topics in Management and Planning (3-0)3
Courses may include decision theory, budgeting, new managerial perspectives, affirmative action, crime scene management and issues in court administration.

Area III: Crime and the Community

44-520 Crime and the Community (3-0)3
Examines the factors that affect both personal and property crime in different communities. A variety of community-oriented police, court and correctional crime control strategies will be critically analyzed.

***44-521 Criminological Theory** (3-0)3
A detailed examination of the best known and most influential theories of crime causation. Topics include: (1) theory construction, (2) hypothesis testing, (3) theory integration, and (4) the links among theory, research and policy.

44-522 Victimology (3-0)3
An examination of the characteristics and life styles of crime victims and the impact of their victimization. The treatment of victims by the criminal justice system will be examined along with possible reforms in these approaches.

44-533 Elite Deviance and White Collar Crime (3-0)3
Examines the systematic violation of the laws and ethics of business and politics. The structure of power and privilege in relation to both political and economic deviance.

44-561 Minorities and the Criminal Justice System (3-0)3
Both social and legal consequences of racism and discrimination will be discussed as they pertain to minorities and the criminal justice system.

44-621 Crime and Crime Prevention in Public Places (3-0)3
Examination of current theory and research on crimes in schools, libraries, museums, mass transit, parks, and other public places. Crime prevention and security programs appropriate for these public places will be emphasized.

44-622 Family Violence: System Response (3-0)3
The causes and consequences of intrafamily violence will be examined. Topics will include child abuse and neglect, sexual abuse, spouse abuse, and abuse of the elderly. Alternative techniques for dealing with these problems will be stressed.

44-635 Constitutional Rights in Criminal Procedure (3-0)3
An examination of constitutional rights through the most recent decisions. This includes an analysis of the 1st, 4th, 5th, 6th, 8th, 9th and 14th amendments (i.e., search and seizure, arrests, bail, juries, trials, cruel and unusual punishment, etc.)

44-650 Community-Based Correction (3-0)3
The history and development of programs relating to community treatment of offenders; the philosophies and programs dealing with the rehabilitation and integration of the offender into society.

44-675 Community Relations for Criminal Justice Professionals (3-0)3
Research underlying the ideal of effective communication and persuasion. The application of communication theory to relevant situations. Preventing and dealing with potential crises.

44-682 Special Topics in Crime and the Community (3-0)3
Topics may include victim compensation, sexual offenders, crisis management, comparative studies of crime and crime prevention, women and crime and intensive supervision in probation and parole.

Department of Psychology

Department Chairperson: Jon Hellstedt, Associate Professor; A.B., Augustana College; M.Div., Yale University; Ph.D., Boston University.
Graduate Coordinator: Linda Silka, Professor; B.S. Oklahoma State University; M.A., Ph.D., Kansas University.
Faculty: Meg Bond, Assistant Professor; B.A. Stanford University; M.A., Ph.D., University of Oregon; Janet Burke, Professor; B.S., M.Ed., Ph.D., Boston College; Joan B. Cannon, Associate Professor; B.A., St. Mary's College; Ed.M., Boston University; Ed.D., Clark University; Kathleen Hulbert, Associate Professor; A.B., Northwestern University; Ed.M., Boston University; C.A.G.S., University of New Hampshire; Ed.D., Boston University; David Landrigan, Associate Professor; B.S., Tufts University; M.A., Ph.D., University of New Hampshire; Charlotte Mandell, Associate Professor; B.A., Brooklyn College; M.A., Ph.D., Columbia University; Anne Mulvey, Associate Professor; B.A., Barat College; Ph.D., City University of New York; Charles Nikitopoulos, Associate Professor; A.B., Suffolk University; M.A., New School for Social Research; Ph.D., Boston College; Ronald M. Pickett, Associate Professor; A.B., Dartmouth College; M.A., PhD., University of Michigan; Allie Scruggs, Professor; B.S., Ed.M., Ed.D., Boston University; Richard Siegel, Associate Professor, A.B., Harvard College; M.S., Yale University; Ph.D., Boston University; Mary Roth Walsh, Professor; B.S., Mount Mary College; M.S., Cornell University; Ph.D., Boston University.

Master of Arts in Community Social Psychology

Philosophy and Objectives of the Program

Community social psychologists study relationships between social and environmental forces and the psychological well-being of people. They seek to understand how individuals and groups are affected by such social influences as employment and educational opportunity, organization and delivery of public services, and the structure

and climate of the many social systems within which people live and work.

This master's level program in Community Social Psychology has two main objectives. The first is to provide its students with a rich and practical understanding of how organizations influence well being, adjustment and growth. The second is to equip students to address human problems in a wide variety of social settings. These objectives are met through a balanced program of classroom study and practical field experience, with emphasis on skills-oriented courses in systems analysis, research methods and intervention techniques. Graduates will be prepared to assume professional roles in community organizations, in public institutions or in business and industry.

This program meets the needs of students from various academic and occupational backgrounds. It attracts recent undergraduates from such fields as Psychology, Sociology, Political Science, Health, and Education. For those already working, it can enhance the skills and career development of counselors, social workers, nurses, teachers, government workers, administrators, and mid-level managers in many public and private sector positions.

Admissions Requirements

The Community Social Psychology program at the University of Lowell is designed not only for recent college graduates but also for older and non-traditional students with experience in a variety of work and community settings. The requirements for admission include the following:

1. An undergraduate average of "B" or better in the field of psychology or a related major. Students from other major fields are invited to apply but may be asked to complete some undergraduate requirements. All applicants should have completed a basic statistics or research methods course; students lacking this prerequisite must fulfill this requirement prior to matriculation.
2. Acceptable performance on the Graduate Record Examination Verbal and Quantitative Aptitude Section, or on the Miller Analogies Test.
3. Three letters of recommendation related to the applicant's educational and professional qualifications.
4. A personal letter including a statement about the applicant's professional interests, educational and work qualifications, and future goals.
5. Prospective candidates may be requested to participate in an interview with members of the program's admissions committee.

Transfer Credit

Matriculated students in Community Social Psychology are allowed to transfer up to 10 credits of course work completed at other accredited universities provided that such courses are within the content area of community social psychology and do not involve credit for field experience or professional work. Such transfer credit is subject to the approval of the Student Affairs Committee and the Graduate School.

B.A./M.A. Option

Undergraduate psychology majors at the University of Lowell may enroll in a B.A./M.A. program that allows students to complete both degrees in five years. Additional information on the B.A./M.A. option is available from the Graduate Coordinator.

Part-time Study and Non-Degree Status

While the program in Community Social Psychology provides for full-time study, part-time students are encouraged to apply. In fact, the majority of students complete their program on a part-time basis. Courses are offered at late afternoon and evening hours to accommodate students who are employed.

Students not pursuing an advanced degree or who wish to begin their graduate study without first applying for matriculated status are invited to register as non-degree students for specific graduate courses on a space-available basis. Such students need meet only the first of the admissions requirements listed above. If a non-degree student later applies for acceptance into the master's program, his/her application will be treated equally with those of other new applicants, though performance in graduate courses taken at the University may be used as an additional admissions criterion. Non-degree students accepted as matriculated students may transfer a maximum of 12 credits earned at the University toward the Master's degree.

Graduate Advisor

Each newly-matriculated student in the program will be assigned to an advisor from among the faculty of the graduate program. The student will meet with his/her advisor on a regular basis throughout the years of study to discuss course selections, planning for practica, and the development of the thesis or project. Once a student selects a faculty supervisor for his/her thesis or project, this faculty member takes over as graduate academic advisor.

Degree Requirements

Credits

A total of 36 academic credits, at least 26 of which must be taken at the University of Lowell with a grade average of "B" or better, is required for the completion of the degree.

The 36 credits for the Master's degree are divided as follows:

Coursework Required (47.501, 47.512, 47.520, and 47.525)	12 credits
Electives	12 credits
Practicum	6 credits
Thesis or Project	6 credits
TOTAL	36 credits

Students are encouraged to participate actively in tailoring their program to achieve specific career and professional goals. This may be done through careful selection of coursework, independent study, practicum, and thesis or project experience. A limited number of approved courses taken outside the department may count as electives when these strengthen a student's identified area of interest.

Thesis or Project Requirement

The thesis or project is an original piece of work in the student's area of specialization. The thesis is a faculty supervised research activity; the project is a faculty supervised change-oriented activity. Each of these provides an opportunity for the student to demonstrate skills and knowledge acquired in the program and to make an original contribution to the field of Community Social Psychology. Students may register for 3, 6, or 9 credits in 47.751 while doing thesis or project work, but no more than 6 credits of 47.751 can be counted toward the 36 credit degree requirement. Students typically initiate the thesis/project after completion of 12 to 18 credits.

Research Opportunities

In addition to the basic curriculum, the Community Social Psychology program offers opportunities for students to be involved in interdisciplinary and collaborative community research projects working with faculty from the Psychology Department, from other social sciences and related disciplines, and with members of the community.

Course Descriptions

47-501 Applied Developmental Psychology (3-0)3

Provides a life span developmental perspective on individual and social adaptation and change. Examines appropriate theory and research, and illustrates the influences of environmental, social and cultural factors.

47-502 Seminar in Community and Social Psychology (3-0)3

This course is designed to acquaint the student with new developments from a broad range of current psychological theory and research and how these developments might affect social and community life.

47-503 Applied Social Psychology (3-0)3
Introduces students to social psychology as an applied discipline. Covers such applied topics as attitude change, aggression, helping behavior, attribution, and interpersonal influence.

47-504 The Family System (3-0)3
Family processes and the interplay between the family and other social, cultural and socio-economic systems. Topics include parental roles, changing family structures, racial and ethnic factors, and interactions between family, work, and community.

47-511 Helping Skills I: Dyads (formerly Community and Social Aspects of Counseling) (3-0)3
The basics of the helping relationship with individuals are covered including interviewing, listening, basic and advanced empathy, goal setting, and implementing strategies for change. The emphasis will be on the dyadic relationship of helper and client, though some applications to larger networks will be covered. The emphasis will be on how to use these techniques in human service settings in the community.

47-512 Applied Research Methods 3-0)3
Considers strengths and limitations of various approaches to community and social psychological research. Develops skills for formulating research questions and translating them into practical study designs. Sensitivity to research ethics as well as its practicality and validity is emphasized.

47-513 Helping Skills II: Groups and Organizations (formerly Communication in Human Organizations) (3-0)3
In this course the student will be exposed to skills in leading groups and consulting to community groups and organizations. The course will cover group and organizational dynamics, leadership skills, conflict resolution, problem solving, goal setting, and program planning.

47-520 Introduction to Community and Social Psychology (3-0)3
Introduces history and comtemporary trends of community and social psychology with focus on how social and environmental forces affect individual and group quality of life. Surveys issues, methods, and applications.

47-523 Women in the Community (3-0)3
An examination of women's roles in the home, community, and work place; examines psychological consequences, social structural influences, and options for change. Topics include: housework and childcare; violence against women; work place stratification issues; and women's contributions to their communities.

47-524 Ethnic and Racial Factors in the Community (3-0)3
Examines the multi-ethnic community and its effects on behavior, with major emphasis on conflict, prejudice and accomodation, as applied to a variety of social settings, including community, institutional and industrial contexts.

47-525 Psychology of the Middle-Sized City: Lowell (3-0)3
Lowell serves as a model for examining the social issues and systems of mid-sized cities. The course considers how diversity, revitalization, neighborhoods, housing, education, and industry affect quality of life.

47-551 Psychosocial Aspects of Maturity and Aging (3-0)3
Covers changes in behavior from adulthood to old age with emphasis on changes in personality, mental health, sensation and perception, intelligence and learning; and those individual, situational and cultural variables that contribute to successful aging.

47-611 Program Evaluation (3-0)3
A skill-oriented approach that considers both formative and summative evaluation techniques. Emphasizes mastery of the technical aspects of the evaluation process.

47-621 Social System Dynamics: Intervention and Change (3-0)3
Examines the structure and dynamics of mental health, educational, medical, industrial, and other systems with emphasis on strategies, theories, and ethics of social change.

47-622 Selected Topics in Community and Social Psychology (3-0)3
Advanced topics in various areas of Community and Social Psychology. Offered regularly, reflecting special interests of the faculty and students, and may be repeated for credit.

Practicum

47-631 Practicum I (1-9)3
47-632 Practicum II (1-9)3
Provides supervised field experience in a setting appropriate to the student's area of specialization, plus on-campus class meetings. Nine to twelve hours of field work a week for two semesters are required. Students begin the Practicum upon completion of 12 and no more than 18 credits.

47-753, 6, 9 Graduate Research in Community-Social Psychology 3, 6, or 9
Prerequisite: Approval of major advisor
For graduate students actively engaged in research or project work leading toward the submission of a written thesis or report. A program of supervised study will be arranged between the student and a faculty supervisor. This course may be repeated for credit, but only a total of 6 credits may be counted toward the Master's degree.

Department of Biological Sciences

Department Chairperson: Thaddeus V. Osmolski, Professor; B.S., University of Rhode Island; Ph.D., Brown University.
Graduate Coordinator: Ilze B. Skare, Associate Professor; B.A., University of Connecticut; Ph.D., Duke University.
Faculty: John I. Bruce, Professor; B.S., Morgan State College; M.S., Ph.D., Howard University. David T. Eberiel, Associate Professor; B.S., Bethany College; M.S., Tufts University; Ph.D., Boston College. Jerome L. Hojnacki, Professor and Acting Dean of the Graduate School; B.S., Southern Connecticut State University; M.S., University of Bridgeport; Ph.D., University of New Hampshire; M.H.A., Clark University. Ethel N. Kamien, Professor; B.A., Brooklyn College; M.S., Ph.D., University of Wisconsin. Robert D. Lynch, Professor; A.B., Northeastern University; M.S., D.Sc., Harvard School of Public Health. John C. Mallett, Professor; B.S., College of the Holy Cross; M.S., Ph.D., University of Rhode Island. Nicholas J. Rencricca, Professor; B.S., St. Francis College; M.S., St. John's University; Ph.D., Boston College. Ezequiel R. Rivera, Professor; B.S., Sul Ross State College; M.S., Purdue University; Ph.D., University of Texas (Austin). Lee-Jun C. Wong, Associate Professor; B.S., National Taiwan University; Ph.D., The Ohio State University.

The following degree programs are available: Master of Science in Biological Sciences; Master of Science in Biological Sciences - Biotechnology Option; and an interdepartmental Doctor of Philosophy program in Chemistry-Biochemistry Option.

Research and Teaching Facilities

The Department is housed in modern teaching and research facilities which include service areas such as animal quarters, X-ray facilities, temperature-controlled animal and plant cell culture incubation chambers, and dark rooms. The Department also maintains a primate research center. Research instrumentation includes transmission electron microscopes, ultracentrifuges, UV-visible spectrophotometers, liquid and deep-well crystal scintillation spectrometers, Coulter counter, a variety of electrophoresis equipment, HPLC and other chromatography equipment, fermenters, and extensive computer facilities.

Faculty Research Interests

The graduate faculty in the Department of Biological Sciences is actively engaged in research in the following areas: biochemistry, molecular genetics, cell biology, immunology, parasitology, physiology, and environmental biology.

Master of Science Degree Programs

The Master of Science in Biological Sciences and the Master of Science in Biological Sciences - Biotechnology Option provide the advanced study and training necessary to conduct independent research at a professional level and to be successful in today's competitive academic and industrial research markets. Students in the program will be encouraged to explore quantitative approaches to the solution of problems in the basic and applied biological sciences. Depending on their career goals, students may choose either research or course work options within the Department, or from the interdisciplinary

Biotechnology option. All candidates for the master's degree are expected to demonstrate sufficient knowledge and skills to pursue independent and creative research activities.

Entrance Requirements and Procedures

Entering graduate students are expected to have a sound preparation in the biological sciences, chemistry, physics, calculus, and statistics. A student found deficient in any of these areas may be required, during the first year, to take appropriate courses to eliminate the deficiencies. The departmental Graduate Coordinator helps plan the entering students' first semester's program of study, acquaints them with research opportunities in the department, and assists in selecting a research supervisor.

Degree Requirements

A minimum of 30 semester hours of graduate level work is required for the Master of Science degree in Biological Sciences. The student has a choice of three options: thesis, project, or non-thesis. Minimal core requirements for all options include 2 semesters (4 credits) of graduate seminar and 12 credits of formal course work selected from departmental electives (exclusive of thesis, project, problems, or other directed studies). The remaining 14 credits may be satisfied by additional electives within the department (thesis, project, problems, or more course work), by transfer credit for approved graduate level biological sciences courses taken at other accredited institutions (10 credit maximum), or by graduate courses taken in related disciplines within the University (e.g., chemistry, environmental sciences, chemical engineering, radiological sciences; 8 credit maximum). There is no formal language requirement.

Thesis Option

In choosing this option, the student concentrates on an in-depth, independent, scholarly investigation of a contemporary biological problem. Credit is allowed for 6-12 semester hours of M.S. Thesis Research. After consulting with the research adviser, the student selects two faculty members (one of whom will be from within the Department) to serve as members of the Thesis Committee. The student presents to the Committee a proposal of intended research and obtains the Committee's approval of the research topic. After completing the master's thesis, the student presents a defense of his /her work in an open seminar.

Project Option

The project option is designed for independent laboratory investigations of a more limited nature than the thesis option. Generally, a project is completed in one or two semesters and credit is given for 3 - 6 semester hours of M.S. Project (no more than 6 credits will be allowed).

Non-Thesis Option

This option offers course work in breadth and depth, and may be of special interest to secondary school science teachers and individuals already employed in academic, hospital, or industrial laboratories. The non-thesis option may be completed during the day on a full-time basis or in late-afternoon or evening sessions on a part-time basis. However, since not all day courses are regularly available in the evening sessions, a part-time student's progress toward the M.S. degree will depend not only on his/her available time and abilities, but also on the scheduling of electives. In some instances, with the consent of a faculty member, an evening student may elect the thesis or project option.

Students whose professional goals are to continue on for the Ph.D. degree, or who plan to seek employment in academic or industrial research laboratories as technicians or junior scientists are strongly urged to choose the thesis or project option in order to succsessfully compete for such positions. Students in the non-thesis option should endeavor to select courses with accompanying laboratories whenever possible.

Professional Internship

Credit (81-500; 3cr) may be requested by individuals who present satisfactory evidence (in the form of a written statement from their supervisor) of having at least one year of experience in secondary school science teaching, or in an academic, hospital, or industrial laboratory setting.

Seminars

Each student is required to complete 2 semesters of graduate seminar. Students in the biotechnology option must take the biotechnology seminar at least once. The other seminar may be either the biotechnology seminar or the regular biology seminar. All other students may choose either one.

M.S. in Biological Sciences - Biotechnology Option

This program provides the in-depth training necessary for graduates to participate effectively in a modern biotechnology laboratory. The core curriculum offers extensive hands-on experience in current techniques and instrumentation. Field trips and seminars afford students an opportunity for interaction with the biotechnology industry. Beyond the core requirements, the student is encouraged to follow an interdisciplinary approach to his/her training by electing courses offered by the Chemical Engineering, Chemistry, Computer Science, or Work Environment departments. The candidate is expected to conduct a research project in one of the recognized areas of biotechnology or to present an innovative application of technology or engineering principles to a biological problem of economic interest. The nature and extent of the investigation will determine its degree credit value.

Core Requirements- Biotechnology Option

81-548	Biochemistry I
81-549	Biochemistry II
81-554	Techniques in Biochemistry
81-567/569	Recombinant DNA Techniques (lecture and lab)
81-576/578	Cell Culture and Hybridoma (lecture and lab)
81-593/595	Immunology (lecture and lab)
81-703,704	Biotechnology Seminar (81-701or 702 may be substituted for one of these)
Plus:	Thesis or Project

Students who enter the program having already completed some of the above courses will consult with an adviser to design a course of study appropriate to their needs.

Recommended Electives- Biotechnology Option

81-558	Industrial Microbiology
81-585	Eukaryotic Gene Expression
81-572	Virology
10-502	Principles of Chemical Engineering I
10-532	Principles of Chemical Engineering II

The sum of core and elective courses must total at least 30 credits.

Five Year B.S./M.S. Program

Outstanding undergraduates may pursue an accelerated five-year course of study leading to the B.S. and M.S. degrees in Biological Sciences. See description at the front of this catalog for further information.

Doctor of Philosophy Degree Program

(Biochemistry Option)

The Department of Biological Sciences and The Department of Chemistry have developed a program in Biochemistry which results in the award of a Ph.D. in Chemistry. For a full discussion of program requirements please see the section on Biochemistry under the Chemistry section of this catalog.

Course Descriptions

81-500 Professional Internship (3-0)3
Credits will be given to individuals who present evidence of having at least one full year of experience in an academic, hospital, or industrial laboratory setting, or in secondary school science teaching.

81-501,502 Selected Topics in Biology (3-0)3, (3-0)3
Current topics in various fields of biology presented in lecture, seminar, or discussion groups. Subject matter varies depending on interests of instructors and needs of students. May be repeated for credit when course content differs.

81-503 Biochemistry of Metabolic Disorders (3-0)3
Prerequisites: Physiology and Biochemistry
This course deals with the biochemistry, pathophysiology, detection and treatment of a number of disturbances in lipid and carbohydrate metabolism including: diabetes, obesity, alcoholism, heart disease, and glycogen storage diseases.

81-510 Limnology (3-0)3
Prerequisites: Principles of Biology, Ecology
Introduction to freshwater environment, considering geology, chemistry and physics of waters as they affect flora and fauna in standing and flowing water. Attention is addressed to basin and channel morphometry, thermal, photic, hydrologic and solvent properties of the medium.

81-512 Limnology Laboratory (0-3)1
A series of laboratory exercises designed to emphasize the material covered in 81-510.

81-518 Experimental Hematology (3-0)3
Prerequisites: Mammalian Physiology, or equivalent.
Physiology of the erythropoietic system, with emphasis on the proliferation and differentiation of hemopoietic stem cells. Abnormalities resulting in hematologic diseases will be discussed.

81-520 Experimental Hematology Laboratory (0-6)2
A series of laboratory exercises and projects designed to employ basic and advanced techniques in hematology and which emphasize the material covered in 81-518.

81-522 Plant Physiology (3-0)3
Organic Chemistry recommended. Concurrent registration in Plant Physiology Laboratory recommended. A critical study of the physiological processes which occur in living plants, with emphasis on the angiosperms. Topics treated are growth and development, water relations, mineral nutrition, respiration, photosynthesis, and nitrogen metabolism. A term paper is required.

81-524 Plant Physiology Laboratory (0-3)1
A series of laboratory experiments and analyses designed to illustrate the material covered in 81-522.

81-529 Biochemical Aspects of Heart Disease (3-0)3
Prerequisites: Physiology and Biochemistry
Consideration of abnormalities in carbohydrate, lipid and protein metabolism which occur in the heart, blood, and arteries during the development of atherosclerosis. Current biochemical methods employed in cardiovascular research are reviewed.

81-541 Advanced Topics in Cell Biology and Physiology (3-0)3
Prerequisite: Biochemistry. Structure and function of the cell: (a) cellular membranes, (b) transport mechanisms, (c) motility, (d) excitable cells, (e) energy transduction mechanisms. May be repeated for credit when content varies.

81-542 Cell Biology (3-0)3
Prerequisite: Biochemistry. Corequisite: 81-544
Ultrastructure and biochemistry of eukaryotic cells: cell membranes and organelles; energy capture and transduction; histochemical and biochemical studies of organelles at the optical and electron microscopic level; cytogenetics; brief discussion of prokaryotic cells. A substantial library investigation is required.

81-544 Cell Biology Laboratory (0-3)1
Corequisite: 81-542. The optical microscope as an analytical tool. Analysis of biological ultrastructure at the optical and electron microscopic level. Cell fractionation. Chromosome preparations. One substantial ultrastructural analysis required.

81-548 Principles of Biochemistry I (3-0)3
Prerequisite: Organic Chemistry (Physical Chemistry is recommended). Primarily for M.S. students in Biological Sciences. Lectures and text assignments on the subjects of protein, carbohydrate, lipid, enzyme and membrane biochemistry will be supplemented with research journal readings.

81-549 Principles of Biochemistry II (3-0)3
Prerequisite: 81-548 or equivalent. This course is a continuation of 81-548 and will include discussions on all aspects of amino acid and nucleic acid metabolism and protein biosynthesis.

81-550 (84-550) Biochemistry I (3-0)3
Prerequisites: Physical Chemistry and permission of instructor. Required of all Ph.D. students in the Biochemistry Option. Course content and requirements are similar to those in 81-548 except that a term paper or seminar presentation based on current published research will be assigned.

81-551 (84-551) Biochemistry II (3-0)3
This course is a continuation of 81-550 and will include topics similar to 81-549.

81-554 Techniques in Biochemistry (1-4)2
Prerequisite/corequisite: Biochemistry
Required of M.S. students in the Biotechnology Option. Emphasis on common techniques and instrumentation employed in modern research laboratories.

81-558 Industrial Microbiology (3-0)3
Selected topics concerned with the use of microorganisms for the production of substances of economic importance. The principles and techniques of fermentation to produce such products as amino acids, antibiotics, vitamins, and organic acids are addressed, with emphasis on metabolic regulation of biochemical pathways and genetics of industrially important microorganisms.

81-563 Electron Microscopy - Theory and Practice (2-6)4
Prerequisites: Biochemistry and permission of instructor
Introduction to electron optics and electron microscopes. Preparation of biological samples for electron microscopy. Operation of electron microscopes. Project required of all students.

81-564 Experimental Hematology: A Study of Current Literature (3-0)3
Prerequisite: 81-518 or equivalent
Group discussions of contemporary literature in experimental hematology. Mediators of blood cell production will be assessed relative to hemopoietic stem cell proliferation and differentiation.

81-567 Recombinant DNA Techniques (2-0)2
Prerequisites: Genetics, Biochemistry, permission of instructor
Corequisite: 81-569
A study of the principles and specialized techniques of cloning, purifying, and manipulating recombinant DNA molecules. A term paper or seminar may be required.

81-569 Recombinant DNA Techniques Laboratory (0-4)2
Corequisite: 81-567
Laboratory experiments and independent projects designed to illustrate current techniques and instrumentation used in genetic engineering. Included are restriction mapping, cloning, plasmid purification, blot hybridization, and DNA sequencing.

81-572 Virology (3-0)3
Prerequisites: Genetics and Biochemistry
A study of bacterial, animal, and plant viruses, including viral structure, modes of replication, biochemistry of the infected cell, genetic properties, and viral oncogenesis. Emphasis is on virus-cell interaction at the molecular level.

81-574 Virology Laboratory (0-4)1
Experiments with bacterial and animal viruses include lytic virus propagation and titering, biochemical, biophysical, and genetic analysis of viral nucleic acids and proteins, and cell culture techniques.

81-576 Cell Culture and Hybridoma (2-0)2
Prerequisites: Genetics, Biochemistry, Immunology
Corequisite: 81-578
Lectures and readings on the biology and culture of animal and plant cells in vitro, the specialized methodologies necessary for hybridoma technology, and the biotechnological applications of each of these areas. A term paper or seminar is required.

81-578 Cell Culture and Hybridoma Laboratory (0-4)2
Corequisite: 81-576
A series of exercises demonstrating the principles presented in 81-576. Techniques will include: media preparation, standard culture procedures and hybridoma methodology.

81-585 Eukaryotic Gene Expression (3-0)3
Prerequisites: Genetics, Biochemistry
A study of the structure and function of eukaryotic genomes. Emphasis will be given to the mechanisms and regulation of gene expression. A term paper on current research topics may be required.

81-593 Immunology (3-0)3
Prerequisites: Microbiology, Genetics, Biochemistry
A study dealing with the nature of the immune response with sections on antibody structure, function and production; antigen-antibody reactions; immunogenetics; and immune regulation, protection and injury.

81-595 Immunology Laboratory (0-3)1
A series of basic laboratory exercises dealing with the preparation, isolation and characterization of antigens, antibodies and effector cells. Semester project required.

81-701,702 Graduate Seminar in Biology
(2-0)2, (2-0)2
Participants are required to present 2 seminars per semester: a short talk on an assigned journal article or topic, and a lecture-length presentation on an advanced topic or their own original research. A fully documented report must accompany the long seminar. Students are also graded on active participation in discussions and will critique each others' presentations.

81-703,704 Biotechnology Seminar
(2-0)2, (2-0)2
Requirement for M.S. students in the Biotechnology Option
The course description is the same as for 81-701, 702, except that the seminars will focus on current topics in biotechnology.

81-711,712 Graduate Topics in Biology
3-0)3, (3-0)3
Prerequisite: Graduate students only; permission of instructor
Selected topics and recent advances not covered in regular courses. Content varies from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary biology.

81-721, 722, 723 Problems in Biology
(0-3)1 to (0-9)3
Prerequisite: permission of instructor
Special research or laboratory projects, or extensive literature surveys, undertaken by the student to expand his/her knowledge in specific fields.

81-733,736 M.S. Project in Biology
(0-9)3 to (0-18)6
An independent study or laboratory project which has been approved as a suitable subject for a Master's Project.

81-743,746,749 M.S. Thesis Research
(0-9)3 to (0-27)9
An independent investigation of a problem which has been approved as a suitable subject for a Master's Thesis.

81-753,756,759 Ph.D. Thesis Research
(0-9)3 to (0-27)9
Thesis research by Ph.D. students who are in the joint Biochemistry Program Option (between the Chemistry and Biological Sciences Departments) and are conducting research with faculty in Biological Sciences.

Department of Chemistry

Department Chairperson: Edwin G.E. Jahngen, Professor; B.S., Bates College; Ph.D., University of Vermont.
Department Coordinator: Eugene F. Barry, Professor; B.S., Villanova University; Ph.D., University of Rhode Island.
Faculty: William W. Bannister, Professor; B.S., Ph.D., Purdue University. Alexandre Blumstein, Professor; B.S., Sorbonne, France; Ph.D., University of Strasbourg, France. Rita B. Blumstein, Professor; B.S., Sorbonne, France; Ph.D., University of Delaware. Stuart B. Clough, Professor; B.S., University of Massachusetts; M.Ch.E., University of Delaware; Ph.D., University of Massachusetts. Rudolf Faust, Assistant Professor; M.S., Ph.D., Eotuos Lorand University of Sciences, Budapest, Hungary. Richard Gross, Assistant Professor; B.S., State University of New York at Albany; Ph.D., Polytechnic University, Brooklyn, New York. Martin Isaks, Associate Professor; B.S., Purdue University; M.S., Iowa State University; Ph.D., University of Cincinnati. Stanley C. Israel, Professor; B.S., Parsons College; Ph.D., Lowell Technological Institute. Albert D. Kowalak, Associate Professor; B.S. College of William and Mary; M.S., Ph.D., Virginia Polytechnic Institute. Kuang-Pang Li, Associate Professor; B.S., M.S., National Taiwan University; M.S., Ph.D., University of Illinois. Irving Lipschitz, Associate Professor; B.A., M.S., New York University; Ph.D., Virginia Polytechnic Institute. Kenneth A. Marx, Associate Professor; B.S., California State University at San Diego; Ph.D., University of California, Berkeley. Melisenda J. McDonald, Associate Professor, B.A., Dowling College, M.A., Ph.D., State University of New York at Buffalo. Chong Wha Pyun, Professor; B.S., M.S., Seoul National University, Korea; Ph.D., Brown University. Harry Rubinstein, Professor; B.S., Brooklyn College; Ph.D., Purdue University. David K. Ryan, Assistant Professor, B.S., LeMoyne College; Ph.D., University of New Hampshire. Joseph C. Salamone, Professor; B.S., Hofstra University; Ph.D., Polytechnic Institute of Brooklyn. Samuel P. Sawan, Professor; B.S., Ph.D., University of Akron. Joseph Sneddon, Associate Professor; B.Sc., M.Sc., Ph.D., University of Strathclyde, Scotland. Sukant Tripathy, Professor; B.S., M.S., India Institute of Technology, Ph.D., Case Western Reserve University. Arthur C. Watterson, Professor; B.S., Geneva College; Ph.D., Brown University. Shan S. Wong, Professor; B.S., Oregon State University; Ph.D., Ohio State University.

Master of Science Degree Program

Study is offered in biochemistry, analytical, inorganic, organic and physical chemistry. This program provides opportunity for advanced study and research training in chemistry, both general and specialized. Provision also is made for the student to elect certain advanced subjects in related fields of mathematics, physics, and engineering.

Diagnostic-Evaluation Examinations

During the week of registration, each entering student must present his/her self for written examinations in the four fields: organic, physical, inorganic and analytical chemistry. The examinations are the American Chemical Society Graduate Level Placement Examinations and are used to help plan the student's program.

Credit Requirements

A minimum of 30 credits is required for the Master of Science degree in Chemistry, 18 credits of which are associated with courses; 12 credits of graduate research are required. Of the 18 course credit minimum, exclusive of research and seminar, a minimum of 15 credits must be taken in chemistry. The remaining course credits (3 or more) may be taken in chemistry or in related fields such as physics, mathematics, biology or engineering. Credit normally is not allowed for 400 level subjects in chemistry except for those designated in the catalog or approved by a student's adviser. Each graduate program in chemistry must include at least three advanced subjects from three of the following areas: organic chemistry, inorganic chemistry, analytical chemistry, physical chemistry, biochemistry or polymer chemistry, unless such requirements have been met previously. Depending upon the student's performance on the diagnostic examinations, his or her advisory committee may recommend that the student take additional courses in the areas of deficiency.

Course Offerings, their Distribution and Program Requirements

Master of Science in Analytical Chemistry

84.514 Advanced Analytical Chemistry
and two courses from the following selection:
84.523 Organic Reaction Mechanisms
or
84.568 Structural Analysis
84.532 Advanced Physical Chemistry
84.550 Biochemistry I
84.403 Introduction to Polymer Science I
84.543 Modern Inorganic Chemistry

Master of Science in Biochemistry

84.550 Biochemistry I
84.551 Biochemistry II

and any two courses from the following section:

84.523 Organic Reaction Mechanisms
or
84.568 Structural Analysis
84.514 Advanced Analytical Chemistry
or
84.580 Advanced Analytical Biochemistry
84.403 Introduction to Polymer Science
84.560 Advanced Physical Biochemistry
or
84.532 Advanced Physical Chemistry

Master of Science in Organic Chemistry

84.523 Organic Reactions, Mechanisms and Structure
84.524 Organic Synthesis
84.568 Structural Analysis

and at least two courses should be selected from the following:

84.532 Advanced Physical Chemistry
84.521 Physical Organic Chemistry
84.550 Biochemistry I
84.543 Modern Inorganic Chemistry

Master of Science in Inorganic Chemistry

84.543 Modern Inorganic Chemistry
84.532 Advanced Physical Chemistry
84.523 Organic Reaction Mechanisms

and one course from the following:

84.514 Advanced Analytical Chemistry
84.550 Biochemistry I
84.551 Biochemistry II

Master of Science in Physical Chemistry

84.531 Statistical Thermodynamics
84.532 Advanced Physical Chemistry
84.513 Spectroscopy
84.523 Organic Reaction Mechanisms
84.543 Modern Inorganic Chemistry
84.540 Chemical Kinetics

Seminar Requirement

Each semester the student is required to attend and participate in the chemistry seminar/colloquium program 84.601,602,603 and 604. In addition, a master's candidate is required to present one seminar.

Thesis Advisory Committee

An advisory committee should be selected jointly by the student and advisor at the earliest possible opportunity. A minimum of three (3) faculty members are required for the master's thesis committee. The student's advisor will serve as the chairperson of this advisory committee. The purpose of this committee is twofold. First, it will be responsible for ascertaining that the student's research was conducted and presented in final form, in a professional and acceptable manner. Perhaps of more importance, the committee will serve in an advisory capacity during the course of the research project. In this spirit it is recommended that the student convene a meeting of the selected committee prior to starting his/her research. The purpose of this meeting is to informally present an outline of the proposed research project.

Doctor of Philosophy Degree Program

Analytical, Inorganic, Organic and Physical Chemistry

The doctoral program in chemistry is designed to provide the student with a background in advanced course work and chemical laboratory techniques that will prepare him or her to carry out, under the guidance of experienced scientists, an original, independent investigation that will lead to an acceptable contribution to the body of contemporary knowledge.

Plan of Program

The doctoral degree normally requires four years of study beyond the bachelor's degree or a minimum of two to three years beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through a conference with the Advisory Committee (or with his or her temporary adviser).

All students entering the doctoral program must take the complete set of evaluation examinations given during the week of registration as described in the section relating to the Master of Science program in Chemistry.

The initial part of the student's program, normally completed at the end of two years of study, is devoted to formal course work. The first year is usually given to subjects in the major branches of chemistry in preparation for area (candidacy) examinations. The second year is devoted primarily to advanced subjects in a special field of concentration.

The second and final part of the program is devoted principally to research leading to the doctoral dissertation. However, the student is encouraged to begin research as early as possible in the program of study.

Language Requirements

Students in all Ph.D. programs must demonstrate satisfactory reading ability in one foreign language and acquire facility in one additional research tool. The research tool may be a second foreign language, a computer language, a statistics course or other skill acceptable to both the Graduate Coordinator and the research advisor of the student. The language(s) selected may not include the native langauge of a student's country of origin. Outlined below are the pathways by which this requirement can be satisfied.

I. Completion of a Language Requirement

A. Achievement of a minimum grade of 50th percentile in the Educational Testing Service (ETS) examination in French, German or Russian. The ETS exams in French, German and Russian will be given three times a year, namely, at the end of August, mid-January and at the end of May. These exams are only available to those students enrolled in doctoral programs administered by the Department of Chemistry. The tests consist of standardized, multiple choice questions, similar to the Graduate Record Examination. Facility with grammar and scientific translation is covered. A score corresponding to the 50th percentile or higher must be obtained and a student may take an exam in a specific language an unlimited number of times.

Note to International Students: If your native language is German, French, Russian or Japanese, English may count as your foreign language if you score at or above the 50th percentile on the TOEFL examination.

B. Completion of a two-semester undergraduate course sequence — The completion of a two-semester course in French, German, Japanese or Russian with an average grade of B or better satisfies this requirement. These courses may be taken at the University of Lowell or at another institution. Japanese language courses are not offered at the University of Lowell. The following courses at the University of Lowell are acceptable:

German: Elementary Technical German I and II (51.113 & 51.114)
or
Intermediate German I and II (51.211 & 51.212)

French: Intermediate French I and II (50.211 & 50.212)

Russian: Elementary Technical Russian I and II (53.113 & 53.114)

Note: No written language examinations prepared by a faculty member will be allowed to satisfy a language requirement.

II. A Research Tool as a Substitute for a Second Language

The following courses represent a selection from which a student may choose a research tool:

92.261 Introduction to FORTRAN
92.265 Introduction to Pascal
92.209 Introduction to BASIC
92.383 Introduction to Statistics
92.386 Statistics for Science and Engineering
92.385 Biostatistics
84.529 Chemometrics - If 84.529 is chosen as a research tool, credit for this course cannot count toward the 27 needed. This course may not

be used as a research tool by students in Analytical Chemistry.

Credit Requirements

Of the 45 minimum credit requirements, a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with at least 18 to be taken in chemistry. The remaining course credits (9 or more, with a student's Advisory Committee having the authority to add 6 additional credits to the minimum in special situations) may be taken in chemistry or in a related field such as biology, physics, mathematics or engineering. Credit is not normally allowed for undergraduate subjects in chemistry except for those so designated in the catalog. Research credits would then make up the remainder of the 45 credit requirements. Planning the program of courses with the student is the responsibility of a student's Advisory Committee.

Written Area Examinations

Upon admission to the Ph.D. program the student must pass exams in his/her major area of specialization. The method of conducting these area exams is decided by the staff in each field of specialization, as follows:

Analytical Chemistry

The area examinations for analytical chemistry will consist of a series of six (6) examinations. The first will be a qualifying examination to determine if the student is prepared to take the remaining five area examinations. The student will have two opportunities to pass the qualifying examination, which will be administered at the beginning of the student's second and third semester of residence. The remaining five examinations will be offered annually, commencing in October and administered at monthly intervals. A minimum of 3.0 out of a possible 10.0 points is required for each individual examination and a total of at least 30.0 out of a possible 50.0 points is required for the successful completion of the Written Area Examination. Failure to perform adequately may result in the student being required to complete a master's degree. Continuation towards the Ph.D. degree will be considered on a case by case basis.

Inorganic Chemistry

The area examination in inorganic chemistry will be a two-part written preliminary examination. Both parts are given in the same week. Students are to discuss with their Advisory Committee the areas to be included in their examination. The preliminary examination must be taken no later than the third year of the student's graduate school enrollment. The student will have two opportunities to pass the written examination. Failure on the second trial will result in removal of the student from the Ph.D. program in Inorganic Chemistry.

Organic Chemistry

Organic students take a series of eight cumulative examinations, given once a month (except December), beginning in September of each year. The examinations are graded pass or fail, and a student must pass four of the examinations. The examinations must be taken in consecutive months. Typically, a student will start the examinations in the second year of graduate study and must complete these examinations by the end of the third year of graduate study.

Physical Chemistry

By the third year of graduate study, a Ph. D. student in physical chemistry must take a comprehensive examination. This is an all-day written examination with questions designed to test the student's physical chemistry background, set up models, and solve them mathematically. The student has two chances to pass the comprehensive examination.

Research Proposal

As part of the area examination(s) a Ph.D. candidate must present an oral defense of an original research proposal within 6 months of completing the written area examinations although a specific program may require the proposal to be presented at an earlier date. With the aid and advice of the Advisory Committee the student selects a suitable subject for investigation, completes a literature survey, outlines the method of approach, and suggests possible results and conclusions. The oral defense of this proposal is conducted by the student's Advisory Committee with other faculty members in attendance. It is taken by the end of the semester following completion of area exams. The topic of the proposal cannot be closely related to or contained within the thesis project.

Chemistry Seminar

During each year of residence the student is required to attend and participate in 84-601, 602, Chemistry Seminar, and 84-603, 604 Chemistry Colloquium. Each doctoral student is required to present two seminars.

Course Requirements

Each student in any of the Ph.D. programs in Chemistry shall take both an advanced course in Physical Chemistry and Organic Chemistry and two courses from Advanced Inorganic, Advanced Analytical, Biochemistry, or Polymer Chemistry unless such requirements have been met previously.

If the results from the diagnostic examinations indicate adequate background in any of the above subjects, substitution by a more advanced subject in the 500 series is recommended. Additional subjects in chemistry or in the field of the minor may be taken in the first year if desired, provided the prerequisites are met.

Since each division (Analytical, Biochemistry, Organic and Physical/Inorganic) has its own specific course requirements, a student intending to specialize in one of these areas is encouraged to meet with the coordinator of the division or consult the handbook of the division.

A. Course Requirements (Ph.D.) in Analytical Chemistry

1. 27 Credits in course work are required.
2. Required Courses:
   - 84.514 Advanced Analytical Chemistry
   - 84.523 Organic Reaction Mechanisms
     or
   - 84.568 Structural Analysis
   - 84.532 Advanced Physical Chemistry
   - 84.543 Modern Inorganic Chemistry

Note: With the exception of 84.514, Advanced Analytical Chemistry, one of the following courses may be substituted for one of the above with the permission of the student's faculty advisor and the analytical coordinator.

- 84.538 Biochemical Mechanisms
- 84.550 Biochemistry I
- 84.403 Introduction to Polymer Science
- 97.511 Biopolymers

Of the remaining 15 credits at least 6 must be in chemistry. The approval of the advisor and analytical coordinator are required for non-chemistry courses. Such courses must be justified as being relevant to the student's course of study.

B. Course Requirements (Ph.D.) in Inorganic Chemistry

Required Courses:

- 84.532 Advanced Physical Chemistry
- 84.543 Modern Inorganic Chemistry
- 84.534 Quantum Chemistry
- 84.540 Chemical Kinetics
- 84.523 Organic Reaction Mechanisms and Structures

One course to be selected from:

- 84.514 Advanced Analytical Chemistry
- 84.550 Biochemistry I
- 84.551 Biochemistry II

The remaining 9 credits may be taken in chemistry, mathematics or engineering.

C. Course Requirements (Ph.D.) in Organic Chemistry

Required Courses:

- 84.515 Chemical Literature
- 84.523 Organic Reactions, Mechanisms and Structures

84.524 Organic Synthesis
84.532 Advanced Physical Chemistry
84.568 Structural Analysis

Two courses selected from the following are also required:

84.514 Advanced Analytical Chemistry
84.534 Quantum Chemistry
84.538 Biochemical Mechanisms
84.543 Modern Inorganic Chemistry
84.550 Biochemistry I
84.403 Introduction to Polymer Science

The rest of the course requirements may be fulfilled by selecting courses from the following list or from graduate courses offered by other departments.

84.515 Advanced Analytical Techniques
84.521 Physical Organic Chemistry
84.527 Stereochemistry
84.561 Advanced Organic Synthesis
84.563 Chemistry of Natural Products
84.565 Heterocyclic Chemistry

D. Course Requirements (Ph.D.) in Physical Chemistry

Required courses:

84.532 Advanced Physical Chemistry
84.523 Organic Reaction Mechanisms
84.543 Modern Inorganic Chemistry

and a choice from the following:

84.513 Spectroscopy
84.514 Advanced Analytical Chemistry
97.503 Advanced Polymer Science

Seminar/Colloquium

During each year of residence the student is required to attend and participate in the seminar/colloquium program (84.601, 602) and (84.603, 604). A Ph.D. candidate is required to present two seminars. The topics of these seminars must be unrelated to the student's thesis project.

Candidacy for the Doctorate in Chemistry

To be admitted to candidacy for the doctorate, a student must:

1. Satisfy the 27 course credit requirement, with a minimum Grade Point Average of 3.0.
2. Pass the area examinations, which includes completion of research proposal.
3. Fulfill the language requirements.
4. Inform the graduate coordinator that the above requirements have been completed.

Courses of Study

84-513 Spectroscopy (3-0)3
Prerequisite: 84-431-432 or equivalent
A presentation of molecular spectra and molecular structure is given to illustrate the empirical results and the theoretical backgroud necessary to interpret the results.

84-514 Advanced Analytical Chemistry (3-0)3
Prerequisite: 84-313 and 314 or the equivalent or the permission of Analytical Chemistry Faculty
This course is required of all students in the Analytical Chemistry and Ph.D. Environmental Studies Program. Principles of modern atomic spectroscopy, various separation methods and electroanalytical chemistry are covered. The course is designed to prepare a student for advanced courses in the area of Analytical Chemistry.

84-515 Chemical Literature (1-0)1
Use of the chemical library, journals, reference works and other technical publications pertaining to chemical subjects. Exercises in finding, assembling and using such data. The student will be expected to assimilate the use of automated information retrieval and conduct computer assisted literature searches.

84-516 Advanced Laboratory Techniques (1-6)3
Prerequisite: Permission of Instructor
A study of the theory and application of the more advanced techniques and equipment in the preparation and purification of organic compounds, including high efficiency fractionation, vacuum and molecular distillation, hydrogenation and reactions in inert atmosphere.

84-517 Glass Working (1-0)1
Prerequisite: Permission of Instructor
Fundamental techniques in the preparation and assembling of glass apparatus.

84-519 Environmental Chemistry (3-0)3
Prerequisite: Permission of Instructor
The chemistry of the oceans, atmosphere and biosphere, source and removal mechanisms of natural and anthropogenic substances, thermodynamic and kinetic models in addition to instrumental analytical methods.

84-521 Physical Organic Chemistry (3-0)3
Prerequisite: 84-523-524 or equivalent
Modern and classical methodology in the study of organic reactions. Linear free energy relationships, tracer methods, orbital symmetry and other selected topics will be covered.

84-523 Organic Reaction Mechanisms and Structures (3-0)3
Prerequisite: Permission of Instructor
Designed to provide insight into how reactions occur and how the reactions mechanism is studied. Emphasis is placed on bonding, substitution and elimination processes, stereochemistry, and conformational analysis.

84-524 Organic Synthesis (3-0)3
Prerequiste: Permission of Instructor
Mechanism, scope and limitations of important selected types of reactions, and designs of synthetic sequences. Emphasis is placed on reduction, oxidation, halogenation, alkylation, and acylation reactions.

84-526 Theory and Applications of Chromatography (3-0)3
Prerequisite: Permission of Instructor
Coverage directed to the performance of the packed and capillary column for gas chromatography and HPLC. Modern injection, detector and pumping systems used in chromatography are also discussed.

84-527 Stereochemistry (3-0)3
The fundamental concepts of optical and geometrical isomerism and the relationship of the stereostructures to the physical and chemical properties of organic compounds.

84-528 Electronanalytical Chemistry (3-0)3
This course is an introduction to the theory and application of electroanalytical chemistry. It includes a discussion of electrode processes, electroanalytical techniques and electrochemical instrumentation.

84-529 Chemometrics (3-0)3
This course is a presentation of mathematical techniques useful for evaluating chemical data. Topics addressed include: parametric statistics, ANOVA, regression analysis, optimization and pattern recognition.

84-531 Statistical Thermodynamics (3-0)3
Prerequisite: 84-432 or equivalent
Fundamentals of equilibrium statistical mechanics, classical and quantum statistics. Molecular theories of gases, crystals and liquids, with emphasis on chemical aspects. Electrolyte and non-electrolyte solutions, polymer and polyelectrolyte systems, chemical equilibria and reaction rate processes.

84-532 Advanced Physical Chemistry (3-0)3
Prerequisite: Permission of Instructor
Extension of introductory physical chemistry. Open to seniors and first-year graduate students in chemistry and related fields. Emphasis is placed on quantum chemistry of atoms and molecules as well as on classical and statistical thermodynamics.

84-533 Physical Chemistry for Environmental Studies (3-0)3
Prerequisite: 84.339 or 84.344, 345
This course covers advanced physical chemistry related to environmental systems and measurements. Topics include the fundamental aspects of solution thermodynamics, electrolytes and non-electrolytes, electrochemical theory, surface chemistry, gas laws, kinetics and spectroscopy.

84-534 Quantum Chemistry (3-0)3
Prerequisite: 84-431 or equivalent
Principles and methods of quantum mechanics with special attention to chemical applications, such as electronic nature of atoms and molecules, vibrations and rotation of molecules, and interaction of radiation with matter.

84-535-536 Advanced Topics in Physical Chemistry (3-0) (3-0)6
Selected topics and recent advances in physical chemistry. Selection of topics is at the discretion of the instructor.

84-538 Biochemical Mechanisms (3-0)3
Prerequisite: 84-422-523 or permission of instructor
Selected biochemical reactions will be presented from the point of view of organic reaction mechanisms. Kinetics, coenzyme and enzyme catalysis and mechanisms of oxidative phosphorylation will be emphasized.

84-540 Chemical Kinetics (3-0)3
Prerequisite: 84-432 or equivalent
The theoretical and empirical treatment of chemical kinetic data as well as the methods of obtaining these data. Determination of the order of reactions, factors influencing rates, application of rate studies in establishing hypotheses for reaction mechanism, collision theory, and absolute rate theory.

84-543 Modern Inorganic Chemistry (3-0)3
Prerequisite: Permission of Instructor
Similar to 84-443/444 but designed specifically for graduate students. Emphasis is placed on the theory of the chemical bond, bonding in complexes, coordination theory, spectroscopic methods, and non-aqueous solvent systems.

84-544 Chemical Applications of Group Theory (3-0)3
Prerequisite: 84-334, 84-543 or equivalent
Properties of groups as applied to chemical systems. Development of the ligand field theory and prediction of electronic and vibrational-rotational spectra.

84-563 Chemistry of Natural Products (3-0)3
Prerequisite: 84-568, 84-311 or equivalent
An advanced subject covering the proof of structure of various types of natural products, approaches to the total synthesis of some and also the biosynthetic pathways.

84-565 Heterocyclic Chemistry (3-0)3
Prerequisite: Permission of instructor
Classification, nomenclature, structure, synthesis and utility of the more important classes of heterocyclic compounds.

84-568 Structural Analysis (3-0)3
Prerequisite: Permission of instructor
Practical application of instrumental data in the determination of the structure of organic compounds. Includes mass spectroscopy, ultraviolet spectroscopy, infrared spectroscopy and nuclear magnetic resonance spectroscopy.

84-585 Nuclear and Radiochemistry (3-0)3
Prerequisite: Permission of Instructor
This course stresses the fundamentals of radioactivity, atomic nuclei, nuclear reactions, reactors and detection and measurement of radiation. Applications of material and anthro-pogenic radioactive tracers to oceanic and atmospheric studies are also presented.

84-586 Spectrochemical Analysis
Prerequisite: Permission of instructor
A study of the instrumentation, theory and practice of atomic absorption, emission, and fluorescence in flames, plasmas, and electrothermal atomizers. Application of these techniques for trace metal analysis in complex samples.

84-587 Laser Based Analytical Methods
Prerequisite: Permission of instructor
A brief overview and introduction to the laser will be followed by the application of the laser in analytical chemistry. Topics covered will be atomic and molecular spectroscopy. A discussion of instrumentation, brief theory and selected results will be presented.

84-601, 602 Chemistry Seminar (1-0)(1-0)2
Required of all graduate students. Presentation of current topics by graduate students.

84-603-604 Chemistry Colloquium (1-0)1
Required of all graduate students. Presentation of current topics by visiting scientists and staff.

84-651 Selected Topics in Chemistry (3-0)3
Prerequisite: Permission of instructor
Advanced topics in various fields of chemistry. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary chemistry.

84-751 Advanced Projects in Chemistry (0-3)(0-3)2
Special projects laboratory undertaken by a student to expand his or her knowledge in specific fields not necessarily related to his or her thesis. Content of project and hours assigned must be approved by the Department Chairperson.

Graduate Research Courses in Chemistry

84-743 M.S. Research in Chemistry 3 credits

84-746 M.S. Research in Chemistry 6 credits

84-749 M.S. Research in Chemistry 9 credits

84-753 Ph.D. Research in Chemistry 3 credits

84-756 Ph.D. Research in Chemistry 6 credits

84-759 Ph.D. Research in Chemistry 9 credits

Polymer Science (Department of Chemistry)

Master of Science in Polymer Science

The Polymer Science Program of the Department of Chemistry offers the student a unique opportunity for advanced study and research training in the growing field of macromolecular science. Provision is made to include the broadest coverage of both practical and theoretical aspects of polymer science, taking advantage of the unique facilities at the University of Lowell in chemistry of macromolecules, plastics engineering and other related fields.

Course Requirements

A candidate for the Master of Science degree in Polymer Science must have a minimum of 18 credit hours of course work, exclusive of research and seminar, as well as complete a thesis based upon original research. Of the credit requirement, a minimum of 15 credits must be taken in the Department of Chemistry. The remaining course credits (3 or more) may be taken in chemistry (polymer science) or in such related fields as plastics, physics, mathematics, biology or engineering. Credit normally is not allowed for 400 level subjects in chemistry, except for those so designated in the catalog or approved by a student's adviser. All students must take 97-601-602, Polymer Science Seminar and 97-603-604, Polymer Science Colloquium each year they are in residence. The first semester of Polymer Science Seminar and Colloquium may be given concurrently with the first semester of Chemistry Seminar and Colloquium.

Although the design of the academic program is the responsibility of the student's Advisory Committee, the following listing provides a suggested core of subjects for program development.

First Semester Subjects

97.503	Advanced Polymer Science I
97.505	Polymer Preparation and Characterization I
97.511	Biopolymers
97.553	Organic Chemistry of Macromolecules
97.601	Polymer Science Seminar
97.701	Graduate Research in Polymer Science
84.532	Advanced Physical Chemistry
84.523	Organic Reaction Mechanisms and Structure

Second Semester Subjects

97.504	Advanced Polymer Science II
97.506	Polymer Preparation and Characterization II
97.512	Properties of Bulk Polymers
97.602	Polymer Science Seminar
97.702	Graduate Research in Polymer Science
84.434	Colloid and Surface Chemistry
84.524	Organic Synthesis
26.523	Plastics Processing Techniques

Language Requirements

There is no foreign language requirement for the Master's Degree in Polymer Science.

Thesis Examination

Each candidate for the master's degree must appear for an oral examination in the field of polymer science before an examining committee. The examining committee will include the student's Advisory Committee plus an additional graduate faculty member. The chairman for the examination shall be the student's thesis adviser. While only members of the examination committee and the Dean of the Graduate School may conduct the examination, all faculty members may attend. The examination is held after the thesis has been accepted and within a period of two weeks prior to the close of the final semester. Applications to take the examination must be filed by the student with the Chairman of the Department of Chemistry at least one month prior to the close of the last semester.

Ph.D. – Polymer Science/ Plastics Engineering Option

Students in the Ph.D. Program in the Department of Chemistry may elect the Polymer Science/Plastics Engineering Option. This doctoral program is organized jointly with the

Department of Plastics Engineering. The program is designed to provide students with a background in advanced course work and laboratory techniques that will prepare them to carry out an original investigation leading to an acceptable contribution to the body of contemporary knowledge in the fields of macromolecules or plastics.

Plan of Program

The doctoral degree normally requires four years of full-time study beyond the bachelor's degree or a minimum of two to three years of full-time study beyond the master's degree. The plan of study pursued by each student is dependent on individual requirements and is developed through conference with his/her Advisory Committee (or temporary adviser).

All students entering the program must take the American Chemical Society Graduate Level placement examinations in organic, physical and analytical chemistry. An evaluation examination in polymer science is given to those who wish to be exempted from 97-503-504.

Requirements for Admission

Requirements for admission into the program are the same as those for students entering other Ph.D. programs in Chemistry. It is the student's responsibility to satisfy any admission requirements stipulated for the Ph.D. in Chemistry.

Undergraduate deficiencies in the student's background must be remedied promptly, usually by the end of the student's second semester. During this period, the student must also successfully complete graduate courses appropriate to his/her background. Students will not be formally admitted to the Ph.D. program if their grade point average is below B.

Advisory Committee

Upon admission the student will be assigned a temporary adviser by the Coordinators of the Graduate Polymer Program and Graduate Plastics Program.The student's major thesis adviser will become the chairperson of the permanent Advisory Committee.

For students who elect the plastics concentration, the permanent Advisory Committee will be composed of four members, two from the Department of Chemistry and two from the Department of Plastics Engineering. One of the committee members from the Chemistry Department will have the responsibility of advising the student in course work and research activities in the field of polymers.

The Advisory Committee will meet at least once each semester to monitor the progress of the student's research.

Program Outline

The initial part of the program is devoted to formal course work. The first year usually is devoted to subjects in major branches of chemistry, polymers, and plastics in preparation for the student's area (cumulative) examinations. The student must choose a research advisor before the end of the second semester and is normally expected to start research during the first summer.

Language Requirements

Pathways for satisfying the language requirements have been described previously under the Chemistry section of this catalog.

Written Area Examinations

Upon formal admission to the Ph.D. program the student must pass cumulative area examinations during the second year of study. These examinations must be taken consecutively. Policy and grading underlying each examination will be announced at the beginning of each academic year.

Each student must also present an oral defense of an original research proposal within six months after the completion of the last area exams.

Course Requirements

Of the 45 minimum credit requirements, a minimum of 27 credits in course work, exclusive of thesis and seminar, is required with at least four courses to be taken in chemistry and polymer science (84 and 97 prefixes). The remaining course credits may be taken in chemistry or in the courses listed below. Credit normally is not allowed for undergraduate subjects in chemistry except for those so designated in the catalog. Research credits would then make up the remainder of the 45 credit requirement. The program of courses is the responsibility of a student's Advisory Committee and must include advanced subjects in the appropriate areas of chemistry, polymers, and plastics. When it is necessary to carry less than the normal credit load of 9 per semester, the student must apply to the chairman of the department through the chairman of his/her Advisory Committee for approval.

Required Courses

The student must take the following core courses:

84.523 Organic Reaction Mechanisms
or
84.568 Structural Analysis
84.532 Advanced Physical Chemistry
97.503 Advanced Polymer Science I
97.504 Advanced Polymer Science II
97.505 Polymer Preparation & Characterization I
97.506 Polymer Preparation & Characterization II
97.512 Bulk Properties of Polymers
or
25.503 Mechanical Behavior of Polymers
26.506 Polymer Structure
26.509 Plastics Processing Theory
26.510 Plastics Processing Theory

In addition, the student must take 84.515 Chemical Literature and must register for Polymer Seminar 97.601/602 and 97.603/604 Polymer Science Colloquium each semester.

The remaining formal course credits may be chosen from the following (other courses may be used with permission of the Dissertation Committee):

97.511 Biopolymers
97.553 Organic Chemistry of Macromolecules
84.434 Colloid and Surface Chemistry and Its Environmental Applications
97.549 Physical Chemistry of Macromolecules I
97.550 Physical Chemistry of Macromolecules II
26.502 New Plastics Processing Techniques
26.504 Processing, Morphology, and Properties
26.507 Plastics Industry Organization
25.512 Plastics Foams
26.513 New Plastics Materials
26.516 Composite Materials
26.518 Product Design
26.521 Polymerization Engineering
26.523 Material & Energy Balances in Plastics Processing
26.531 Survey of Synthetic Fibers & Fiber Structures
26.532 Adhesives and Adhesion
26.533/4 Coatings Science and Technology
26.535 Rubber
26.536 Rheology in Polymer Processing
26.537 Engineering Properties of Plastics
26.543 Survey of Plastics Materials
26.544 Survey of Plastics Processing

Course Descriptions (Department of Chemistry)

97-503 Advanced Polymer Science (3-0)3
Prerequisite: Permission of instructor
Introduction to chain statistics and thermodynamics of macromolecular solutions, methods of study of molecular weight and chain conformation, and the properties of polymers in bulk including viscoelasticity and crystallinity.

97-504 Advanced Polymer Science II (3-0)3
Prerequisite: Permission of instructor
A study of the principles of condensation, free radical, ionic, coordination and ring-opening polymerization. The topics include the effect of polymerization techniques on reaction kinetics and molecular weight, and the evaluation of reactivity ratios in copolymerization reactions.

97-505 Polymer Preparation and Characterization I (0-4)1
Prerequisite: Permission of Instructor
A laboratory course designed to acquaint the graduate student with the techniques used in the synthesis and characterization of macromolecules.

97-506 Polymer Preparation and Characterization II (0-4)1
Prerequisite: Permission of Instructor
An advanced laboratory in polymer science concerned with the instrumental study of macromolecules by utilization of osmometry, light scattering, gel permeation chromatography, vapor pressure osmometry and infrared spectroscopy.

97-511 Biopolymers (3-0)3
Prerequisite: Permission of Instructor
Conformation and configuration of vinyl polymers and polypeptides. Helix-coil transitions in proteins and polypeptides. Biological specificity and macromolecular structure. Synthesis of stereoregular polypeptides. Structure and physical properties of nucleic acids.

97-512 Properties of Bulk Polymers (3-0)3
Prerequisite: Permission of Instructor
Structure and properties of bulk polymers in the glassy, rubbery, and crystalline states. Topics covered include chain statistics, rubber elasticity, crystalline polymers, glass transition, segmental motion and viscoelasticity.

97-549 Physical Chemistry of Macromolecules I (3-0)3
Prerequisite: 97-503 or equivalent
Physical chemistry of polymers, including structure and conformation, chain statistics, molecular weight distributions and averages, polymerization kinetics and classical and statistical thermodynamics of polymer solutions.

97-553 Organic Chemistry of Macromolecules (3-0)3
Prerequisite: 97-503, 504
An advanced study in polymer science concerned with the synthesis of macromolecules and their mechanisms of formation.

97-602 Polymer Science Seminar (1-0)1
Required of all Polymer Science graduate students
Presentation of current topics in polymer science by graduate students.

97-603-604 Polymer Science Colloquium (1-0)1
Required of all Polymer Science graduate students.
Presentation of current topics in polymer science by visiting scientists and staff.

97-651 Selected Topics in Polymer Science (3-0)3
Prerequisite: Permission of Instructor
Advanced topics in various aspects of polymer science. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge in the field of macromolecules.

97-751 Advanced Projects in Polymer Science (0-3)1
Special projects undertaken by a student to expand knowledge in a specific field not necessarily related to the thesis. Content of project and hours assigned must be approved by the Department Chair.

Graduate Research Courses in Polymer Science

97-743 M.S.Research in Polymer Science
3 credits

97-746 M.S. Research in Polymer Science
6 credits

97-749 M.S. Research in Polymer Science
9 credits

97-753 Ph.D. Research in Polymer Science
3 credits

97-756 Ph.D. Research in Polymer Science
6 credits

97-759 Ph.D. Research in Polymer Science
9 credits

Candidacy for Ph.D. Chemistry-Polymer Science/Plastics Engineering Option

To be admitted for candidacy for the doctorate, a student must:

1. Satisfy the 27 course credit requirement with a minimum grade point average of 3.0.
2. Pass the area examinations which includes completion of the research proposal.
3. Fulfill the language requirements.
4. Secure the approval of his/her Advisory Committee and the Graduate Coordinator of the Department of Chemistry.

When these requirements have been fulfilled, the Graduate Coordinator of the Department of Chemistry notifies the Dean of the Graduate School in writing and recommends that the student be placed on the list of candidates for the Ph.D. degree. Admisson to candidacy in no way guarantees the granting of the degree.

Ph.D. –Option in Environmental Studies

This graduate program is designed as an optional course of study to the traditional Ph.D. in Chemistry for students with backgrounds in engineering (civil, environmental and chemical engineering) and other sciences (physics, biology, etc.) as well as chemistry. Candidates will be exposed to advanced course work in chemistry and environmental engineering and will be able to choose an area of specialization that best suits their interests and previous experience. A combination of faculty from Chemistry, Work Environment and Civil Engineering with a variety of research expertise gives this program unique characteristics and affords the student the opportunity to perform practical interdisciplinary research. It is expected that most students will require at least four years beyond the bachelor's degree and two years past the master's degree.

Entrance Requirements

The applicant will have an earned bachelor's degree in one of the following fields: chemistry, chemical or civil engineering, biology, environmental sciences, geology or physics. Students will be expected to have satisfactorily completed undergraduate courses in analytical, organic, and physical chemistry, physics and calculus. However, applicants who have not completed courses in these areas of chemistry may remedy their deficiencies while in the program and, therefore, are encouraged to apply. Admissions will be determined by a committee consisting of faculty from the Chemistry, Work Environment, and Civil Engineering Departments.

Program Outline

A total of 57 credits are required for the Ph.D. program. Of these, at least 36 credits must be in course work exclusive of seminar and the rest is usually in thesis research. Courses shown below are divided into three categories: core course requirements (9 credits), areas of specialization (15 credits), and elective courses (12 credits). Additional elective courses from other departments may be substituted with the approval of the student's Advisory Committee. In addition, full-time students must register for 84.601/84.602 or 18.502 Environmental/Analytical seminar every semester. Each student will be required to give two seminars on current research topics during their graduate career. Students in the Environmental program must select a thesis advisor by the end of the second semester. At this time, an Advisory Committee is appointed and a plan of study is established. The Advisory Committee will consist of the thesis advisor, two members from the Chemistry Department and two members from the Civil Engineering Department. An additional member from an another department may also be added if agreed upon by the student and thesis advisor. Students must maintain a 3.0 cumulative average in order to continue in the program.

Written Area Examinations (Cumulative Examinations)

Beginning in the second year of study, the student must pass examinations in their major area of specialization. The examinations are administered by the student's graduate committee and are based on completed course work, seminars, and accepted theory in the field of study. Environmental studies students take six cumulative examinations, each of which focuses on a given area of environmental science and analytical chemistry. Students must take the examinations consecutively.

Research Proposal

A Ph.D. candidate must submit an original research proposal and successfully pass an oral defense of that proposal in his or her second or third year of study. After consulting with the Advisory Committee, the student selects a suitable subject for investigation, completes a literature survey, outlines the method of approach, and suggests possible results and conclusions. The oral defense of this proposal is conducted by the student's Advisory Committee with other faculty in attendence. The proposal must be defended within three months following completion of the cumulative examinations.

Required Courses (24 credits):

I. Core Courses (9 credits)

84.514 Advanced Analytical Chemistry
84.532 Advanced Physical Chemistry
or
84.533 Physical Chemistry for Environmental Studies
84.523 Organic Reaction Mechanism
or
84.568 Structural Analysis

II. Areas of Specialization (15 credits)

a. Analytical /Environment

14.567 Environmental Chemistry I (Aquatic Chemistry)
14.568 Environmental Chemistry II (Fate and Transport)
84.519 Environmental Chemistry II (Marine Chemistry)
84.526 Chromatography
84.564 Spectrochemical Analysis

b. Water Environment

14.567 Environmental Chemistry I (Aquatic Chemistry)
14.568 Environmental Chemistry II (Fate and Transport)
84.519 Environmental Chemistry II (Marine Chemistry)
14.562 Groundwater Hydrology
14.561 Physical Chemical Treatment Processes

c. Air Environment

18.571 Air Pollution Phenomenology
18.523 Air Resources Management & Control
18.573 Air Pollution Laboratory (Monitoring and analysis)
14.568 Environmental Chemistry II (Fate and Transport)
92.591 Statistical Modeling and Data Analysis

III. Elective Courses (12 credits)

84.533 Physical Chemistry for Environmental Studies
84.532 Advanced Physical Chemistry
84.523 Organic Reaction Mechanisms
84.568 Structural Analysis
84.519 Environmental Analytical Chemistry
14.567 Environmental Chemistry I (Aquatic Chemistry)
14.568 Environmental Chemistry II (Fate and Transport)
84.519 Environmental Chemistry III (Marine Chemistry)
84.526 Chromatography
84.564 Spectrochemical Analysis
14.562 Groundwater Hydrology
14.561 Physical Chemical Treatment Processes
18.568 Environmental Laboratory
18.571 Air Pollution Phenomenology
18.523 Air Resources Management
18.573 Air Pollution Laboratory (Monitoring and Analysis)
93.415 Advanced Atmospheric Dynamics I
93.416 Advanced Atmospheric Dynamics II
93.430 Atmospheric Diffusion
18.572 Energy and the Environment
92.591 Statistical Modeling and Analysis
14.565 Industrial Waste Water Treatment Processes
18.510 Water Resources Management
18.522 Solid Waste Management (Municipal, Industrial and Hazardous)
18.525 Epidemiology for Environmental Studies
18.527 Environmental Law
19.501 Industrial Hygiene
81.xxx Wetlands Ecology
84.515 Chemical Literature
98.501 Radiation Safety and Control
98.503 Radiation Biology
98.508 Environmental Toxicology and Epidemiology

Ph.D – Option in Biochemistry

The Department of Chemistry with the Department of Biological Sciences has developed a program in biochemistry which results in the award of a Ph.D. in Chemistry. This program draws upon the special and diverse talents of both faculties, and provides the chemistry graduate students with both in-breadth class work and in-depth thesis research. Emphasis is on the application of modern techniques and concepts of physical and chemical science to the solution of problems of current interest in biology and medicine.

Admission Requirements and Removal of Undergraduate Deficiencies

Admission to the program requires demonstration of an acceptable B.S., B.A., or M.S. degree in chemistry, biology, biochemistry or other related science. Students will be expected to have completed two semesters each of general, organic and physical chemistry as well as introductory biology. Qualifying examinations will indicate deficiencies in any of these areas. They then must be removed by enrolling in the corresponding undergraduate course during the first year in the program.

Academic Standards for Retention in the Biochemistry Program

The graduate student is expected to maintain an average of B or better in all his/her graduate-level courses. All other department requirements must also be met.

Language Requirements

The language requirements are those described in a previous section on Chemistry Dept. Ph.D. requirements.

Degree Requirements

There are 45 credits that are required for the Ph.D. in Chemistry,

Biochemistry Option. A total of 27 of these must be in formal courses while the remaining 18 may be accrued in Chemistry Seminar credits (84.601) and Graduate Research (84.701). Of the 27 required hours of graduate course work, the Biochemistry Program requires that 18 hours are in the specific courses delineated below:

		Credits
84.523	Organic Reaction Mechanisms	3
84.550	Biochemistry I	3
84.551	Biochemistry II	3
84.538	Biochemical Mechanisms	3
84.560	Advanced Physical Biochemistry	3
84.580	Advanced Analytical Biochemistry	3

The remaining courses (a minimum of 9 hours) may be selected from course in the Chemistry or Biology Departments as long as they are graduate level. The choice should be made in conjunction with the advisor. Below is a list of suggested courses.

		Credits
84.523	Organic Reaction Mechanisms and Structure	3
84.527	Stereochemistry	3
84.532	Advanced Physical Chemistry	3
84.568	Structural Analysis	3
84.515	Chemical Literature	3
81.567	Recombinant DNA Techniques	2
81.569	Recombinant DNA Laboratory	2
81.576	Cell Culture and Hybridoma	2
81.578	Cell Culture and Hybridoma Laboratory	2

		Credits
81.585	Eukaryotic Gene Expression	3
81.593	Immunobiology	3

Seminars

During each semester in residence all full-time students must register for a one-credit seminar course and attend one seminar each week, as required by the Chemistry Department. The student is required to present two one-hour presentations during his/her residence.

Research

A. Initiation of Research - Preceptor Selection Procedure

The dissertaton research of each graduate student may be initiated at any time but not later than the end of the second semester in the program. The student is advised to make serious efforts, prior to the summer following his/her first entrance to the program, to initiate faculty research interviews and attempt to identify the area of his/her research interest and particular research group which may be suitable for pursuing his/her research goals.

B. Advisory Committee

Mandatory rotations through prospective research preceptors' laboratories during the first year of residency will aid the student in choosing a research advisor. After the student has chosen his/her research preceptor (during the second semester of residency), an Advisory Committee will be appointed to monitor the progress of the student's research at least twice a year. The Advisory Committee will be a permanent part of the student's examination committees.

Examinations

A. Qualifying Examination

The Biochemistry Ph.D. program requires that students take the qualifying examinations described in the previous section under Chemistry Departmental requirements. These exams are meant to be diagnostic for deficiencies in core subject areas in which students may be asked to take remedial courses.

B. Comprehensive Examination

Part 1. The Cumulative Examination

Ten cumulative examinations will be offered during the academic year, each worth 10 points. The subject material for these exams will be announced at least 2 weeks in advance of the exam date. To satisfy the requirements, each student must score a total of 50 points by the end of his or her second year in residence. In addition, on at least two exams a student must achieve grades of 7 or higher. If the requirements are not met, each individual case will be reviewed and a decision will be made to permit an extension or to terminate the individual with an M.S. degree.

Part 2. Oral Research Proposal

Within six months of satisfying the cumulative exam requirement, but not later than June of the second year, the student will be required to present and defend, orally, a research proposal in an area of biochemistry related to but not identical to that of his/her thesis. A written copy of the proposed research must be distributed to the Examination Committee at least one week prior to the examination.

The Examining Committee will be composed of four faculty members chosen after consultation by the student with his/her preceptor. All members of the university community are welcome to attend these examinations.

Failure to perform adequately in either the written proposal or the oral defense may result in the student being required to complete an M.S. degree. Continuation toward a Ph.D. degree will be judged on a case by case basis.

Admission to Candidacy for the Doctorate

To be admitted to candidacy for the doctorate, a student must:

1. Complete all required courses with necessary grade point average. There is an absolute minimum cumulative grade point average (GPA) requirement of 3.0 for all graduate work. At the end of the first semester, if a student is found to be below the minimum GPA, a written warning will be issued, placing the student on probation. If the cumulative GPA is not raised to 3.0 or higher by the end of the second semester in residence the student will automatically be dropped from the Ph.D. program but allowed to continue toward a master's degree in chemistry with the approval of the graduate committee. While completing the M.S., a candidate must have a minimum GPA of 3.0 and maintain that GPA throughout the remainder of his or her career.

   Upon successful completion of the Master of Science degree, the student may reapply for admission to the doctoral program. Each case will be reviewed on an individual basis by the graduate Committee. Students reentering the Ph.D. program will then satisfy all the requirements for the degree including accruing 50 cumulative exam points from the time of reentry, presentation of their research proposal, completion of their research and thesis defense. Seminar presentations and course work accomplished to complete the master's degree will, of course, be cumulative.
2. Pass the General Examination and, if necessary, the qualifying examination.
3. Fulfill the language requirement (as outlined by the Chemistry Department).
4. Pass the cumulative examinations.
5. Successfully present and defend the Oral Research Proposal.
6. Secure approval of his/her research preceptor and the biochemistry committee.

When these requirements have been fulfilled, the Biochemistry Program Curriculum Committee will recommend that the graduate coordinator of the Department of Chemistry notify the Dean of the Graduate School to place the student on the list of candidates for the Ph.D. degree. Admission to candidacy in no way guarantees the granting of the degree.

Successful performance of an original research project, completion of a written dissertation and subsequent successful public presentation and defense of the dissertation research will culminate in granting of the Ph.D. degree in Chemistry.

Required Courses of Study

84-538 Biochemistry Mechanisms (3-0)3
Prerequisites: 84-551 or Permission of Instructor
Discussion of various biochemical reactions from the point or view of organic reaction mechanisms. Kinetics, coenzymes and methods of study of enzyme catalysis and mechanisms will be emphasized.

84-550 Biochemistry I (3-0)3
Prerequisite: 84-222 or 84-224, 84-335 or 84-344 or Permission of Instructor
An advanced study of the structure and properties of proteins, nucleic acids, carbohydrates and lipids, including kinetics and mechanisms of enzyme action, and detailed description of metabolic pathways of carbohydrates and lipids.

84-551 Biochemistry II (3-0)3
Prerequisite: 84-550 or permission of instructor
A continuation of 84-550 with emphasis on metabolic pathways of amino acids and nucleic acid, biosynthesis of proteins and selected topics in molecular biology and various areas of biochemistry.

84-560 Advanced Physical Biochemistry (3-0)3
Prerequisites: Biochem. I 84-550, and P. Chem. 84-334 or equivalent
Physical chemistry encompasses a group of principles and methods helpful in solving many different types of problems. This course will present selected principles of thermodynamics, kinetics, statistical thermodynamics and quantum mechanics as they are applied to biochemical systems. Various experimental techniques will be discussed in view of their importance in biochemical research.

84-580 Advanced Analytical Biochemistry (3-0)3
Prerequisites: 84-550 or permission of instructor
Analytical Biochemistry involves the separation, detection, and analysis of biological molecules. This course addresses advanced theory and applications of contemporary biochemical techniques and instrumentation. Topics covered include chromatographic and electrophoretic separation techniques, detection of biomolecules by spectroscopy and radiochemical methods, biological preparations, and structural analysis of proteins, nucleic acids, polysaccarides, and lipids.

Graduate Research Courses in Biochemistry

84-753 Ph.D. Research in Biochemistry
3 credits
84-756 Ph.D. Research in Biochemistry
6 credits
84-759 Ph.D. Research in Biochemistry
9 credits

Elective Courses

For course descriptions of suggested courses see appropriate listings in Biology and Chemistry.

Computer Science Department

Department Chairperson: Giampiero Pecelli, Professor; B.A., Eastern Washington State College; Ph.D., The Johns Hopkins University.

Graduate Coordinator: Robert Lechner, Professor; B.S.E.E.,M.S.E.E., Carnegie-Mellon University; Ph.D., Harvard University.

Faculty: Arun Arya, Associate Professor; B. Tech., Indian Institute of Technology, Kanpur; Ph.D., University of Rochester; James Canning, Assistant Professor; B.S., University of Maine at Orono; M.S., Iowa State University; Ph.D., Virginia Polytechnic Institute; Georges G. Grinstein, Associate Professor; B.S., City College of New York; M.S., New York University; Ph.D., University of Rochester; Ray Gumb, Professor; B.S., Massachusetts Institute of Technology; M.A., Emory University; Ph.D., Lehigh University; Jesse M. Heines, Associate Professor, B.S., Massachusetts Institute of Technology; M.S., University of Maine; Ed.D., Boston University; Byung-Guk Kim, Assistant Professor; B.S.E.E., Seoul National University; M.S.E.E., Ph.D., University of Massachusetts at Amherst; John Koegel, Assistant Professor; B.S., M.S., Massachusetts Institute of Technology; Ph.D., Technical University of Graz; Patrick Krolak, Professor; B.S., University of Chicago; M.A., D.Sc., Washington University; David L. Landskov, Assistant Professor; B.A.,M.S., University of Mississippi; William Moloney, Associate Professor; B.S., M.S., Lowell Technological Institute; David Pitts, Assistant Professor; B.S., M.S.,Ph.D., Georgia Institute of Technology; Jerry Pocock, Assistant Professor; B.S., University of Rochester; M.S., Ph.D., University of Massachusetts at Amherst; John C. Sieg, Assistant Professor; A.B., Dartmouth College; M.S., University of Lowell; Ph.D., Boston University; Stuart Smith, Associate Professor; B.A., Rutgers University; M.F.A., Brandeis University; Ed.D., University of Massachusetts at Amherst; Charles Steele, Associate Professor; A.B.,A.M., Boston College; M.S.E.E., Northeastern University; M.Sc., Boston University; Thomas Wilkes, Assistant Professor; B.S., M.S., Ph.D., Georgia Institute of Technology.

Visiting Faculty: Haim Levkowitz, Visiting Assistant Professor; B.A., University of Haifa; M.S.E., Ph.D., University of Pennsylvania.

Adjunct Faculty: George A. Champine, Adjunct Professor; B.S., MS., Ph.D.,University of Minnesota; Ramasamy Jesuraj, Adjunct Professor; B.S., M.Sc., University of Madras; M.S., Concordia University; Ph.D., McGill University; Jeremy Kuo, Adjunct Professor; B.S., National Tsing-Hua University, Taiwan; M.S., Ph.D., Ohio State University.

The Graduate Program in Computer Science

Objectives and Intent

The graduate program has as its primary goal the education of computer scientists of sufficient breadth and sophistication to be leaders in both industrial and academic environments. It is distinguished by its emphasis on engineering aspects of Computer Science, with substantial exposure to the management and design of large software systems; robotics and industrial applications; VLSI design and applied graphics. This mission is supported by the Center for Productivity Enhancement of the University of Lowell and, within the Department, by the Graphics Laboratory, the VLSI Laboratory, the Artificial Intelligence Laboratory and the Systems Laboratory.

The program is intended primarily for students with undergraduate degrees in computer science, or for those who have completed a degree in a related area (electrical engineering, mechanical engineering, mathematics, physics, management, etc.) and possess a substantial background in computer science. Recognizing the often interdisciplinary nature of computer science applications, the program features cooperation with allied departments in the Colleges of Arts and Sciences, Engineering, and Management. Students with strong interdisciplinary interests and abilities will be encouraged and advised on an individual basis.

The Master of Science degree program in Computer Science directs itself to several audiences, from the professional with extensive industrial experience pursuing a terminal degree, to the recent graduate aiming ultimately for an advanced research degree. In all cases, one of its major objectives is to prepare the student for a work environment requiring continued growth.

The Doctor of Science degree program aims to provide a student, whether planning on an industrial or academic career, with a challenging research environment and the capacity to choose either theoretical or applied projects of major scope, depth and originality.

Resources

The Computer Science Department, through its faculty members, the Center for Productivity Enhancement of the University of Lowell, the Graphics Laboratory, the Massachusetts Microelectronic Consortium and an industrial advisory committe, has very strong industrial ties. These are used as a source of ideas for short and long range research projects, hardware donations, student funding, and direction.

To support instructional and research activities, the Department of Computer Science has several large DEC VAXes, Data General MV class machines, a Sequent Balance 21000, an INTEL Hypercube, two Symbolics 3600s, three LMI Lambda dual processor machines, many dedicated graphics processors, Apollo, Sun and VAXStation networks, and a large number of IBM PC, PC-AT, Commodore Amiga and Apple Macintosh II class microcomputers. Most of the larger machines and networks are interconnected by broadband and/or Ethernet. The University computer resources, including a large network of VAXes, are also available and accessible through the broadband network. External access is provided by CSNET and USENET with gateways to BITNET and ARPANET.

Admission Standards and Criteria

Applicants for admission to the graduate program, at both the Master of Science and Doctor of Science level, are expected to have an undergraduate degree in computer science, mathematics, physics, engineering, or a related discipline. They should submit the official application obtainable from the Graduate School. Besides undergraduate transcripts and letters of recommendation, they are expected to submit an official score for the Graduate Record Examination, with the Aptitude part required and the Advanced Computer Science part recommended.

Any student may be required, at the discretion of the department, to complete transitional or remedial courses, possibly without graduate credit. To be considered for fully matriculated status in the graduate program, prospective students are expected to complete or have completed coursework in computer science and mathematics equivalent to that required of all students completing the junior year in the Computer Science Department undergraduate program at the University of Lowell.

Admission to the Doctor of Science degree program requires the demonstration of knowledge of computer science at the master's degree level, as evidenced by the successful completion of appropriate coursework. To be admitted to candidacy, the doctoral student must pass the written departmental qualifying examinations. At a subsequent oral examination, the student, under the direction of a faculty advisor, will propose a thesis topic and demonstrate his/her qualifications to pursue the research. Preparation of the thesis

will be directed by a faculty advisor, and the completed thesis will be defended before a committee named by the department. Representatives of industry and other universities may participate in thesis direction and support.

Financial Support

The department has a limited number of teaching assistantships available to qualified graduate students. These assistantships can be renewed for up to four years and include a stipend varying from $7,000 to $9,000 per year plus tuition remission. Other support is available through the funded research programs in the departmental laboratories.

Degree Requirements

Master of Science Degree Requirements: Each degree candidate will be required to pass, with an average of B or better, and not more than two grades below B, the following minimum number of credits, distributed to include one major and one minor area:

Core courses (91.502, 91.503, 91.515, 91.523, 91.551)	15 credits
Major area (2 courses beyond the core)	6 credits
Minor area (2 courses beyond the core)	6 credits
Elective (exclusive of 91.500)	3 credits
Total	30 credits.

An optional master's thesis can be substituted for at most six credits, and can be used to substitute for one course in a major area and an elective. The thesis is recommended of all students planning to continue past the Master of Science degree.

Doctor of Science Degree Coursework Requirements (beyond the M.S. degree):

Major area	6 credits
Minor area I	6 credits
Minor area II	6 credits
D.Sc. Thesis	24 credits
Total	42 credits.

The major and minor area course requirements for the Doctor of Science degree shall be above and beyond the corresponding requirements for the master's degree, but may continue and deepen specializations begun at that level.

The other formal requirements for the Doctor of Science degree include the completion of a written departmental qualifying examination covering the material of the master's degree core courses and of appropriate material from the area of programming language design and implementation; the submission and defense at an oral examination of a thesis proposal, and the final defense of the completed thesis through another oral examination.

Graduate Course Descriptions

91-500 Fundamentals of Computer Science (3,0)3
Prerequisite: three semesters of calculus.
This is a remedial course, not open for credit toward a Computer Science degree. Mathematical topics necessary for graduate study in computer science: review of sets, relations, functions; elementary combinatorics; summation calculus, recurrences, generating functions; logic; machines and languages.

91-502 Foundations of Computer Science (3,0)3
Prerequisites: 91-500 and 91-303.
An advanced introduction to theoretical computer science. This course will cover the fundamentals of automata, formal language and computability theory.

91-503 Algorithms (3,0)3
Prerequisites: 91-500 and 91-303.
Co-requisite: 91-502.
An advanced discussion of data type and structure, assuming substantial prior exposure to the basics. Abstract types, lists, trees, graphs, sets; relevant algorithms and their worst and average case analyses; Fast Fourier Transforms; polynomial, integer and matrix algorithms; introduction to NP-completeness.

91-508 Advanced Analysis of Algorithms (3,0)3
Prerequisites: 91-502 and 91-503.
Continuation of 91-503.
NP-completeness; complexity classes; lower bounds; approximation techniques. Topics from the recent literature.

91-510 Topics in Fundamentals of Computer Science (3,0)3

91-512 Real Time Systems (3,0)3
Prerequisites: 91.503 and 91.515
The aim of this course is to introduce students to the real-time systems domain. Real time systems are those systems in which the correctness of the system depends not only on the logic result of the computation but also on the time at which the results are produced. The course follows a seminar type format in which students are responsible for presenting the various aspects of the real-time systems domain. Several of the areas covered include: 1) specification, design, and analysis, 2) languages, 3) real-time operating systems, 4) architectures and hardware, 5) communication, 6) fault tolerance, and 7) case studies and applications.

91-515 Operating Systems I (3,0)3
Prerequisites: 91-301, 91-308 and 91-503.
The latter can be a co-requisite rather than a prerequisite. A functional level view of multiprocessing operating systems including processor, memory, peripheral and file systems management in batch time-sharing, real time and distributed systems targeted for various hardware. An OS simulation is a required programming project.

91-516 Operating Systems II (3,0)3
Prerequisites: 91-503 and 91-515.
The design and implementation of an interactive multiprocessing operating system to run on a bare hardware system. Separate teams manage the major subsystems with in-class design reviews to coordinate system integration. A functioning system is a class requirement.

91-517 Systems Programming (3,0)3
Prerequisites: 91-503 and 91-515; 91-516 or permission of the instructor.
The design and implementation of assemblers, linkers, loaders, editors and higher level translation software. Various systems software will be integrated under the operating system built in 91-516 to facilitate a complete programming environment.

91-518 Performance Evaluation (3,0)3
Prerequisites: 91-503, 91-515 and permission of the instructor.
Creation of mathematical models of various computer systems and networks; application of queuing theory to evaluation, prediction of behavior and comparison of model performance.

91-519 Distributed Operating Systems (3,0)3
Prerequisite: 91-503 and 91-515
Topics will include: design paradigms for distributed systems; load balancing and work distribution; naming, searching and protection in distributed systems; reliability and fault tolerance; case studies of existing systems. Project required.

91-520 Topics in Operating Systems (3,0)3

91-523 Software Engineering I: Structured Analysis & Design (3,0)3
Prerequisites: 91-301 and 91-503.
A team-based project lab course on the design, implementation and testing of large software projects; life cycle concept, data-flow, data-structure and algebraic specification methods, structured analysis and testing.

91-524 Software Engineering II: Validation and Verification (3,0)3
Prerequisites: 91-503 and either 91-523 or 91-412.
Comparative analysis of program development support systems, structured testing and rapid prototyping tools for large software systems. Introduction to formal specifications and proof-of-correctness. Students will contribute to ongoing software tool development projects.

91-526 Project Management (3,0)3
Prerequisites:91-503 and 91-523
Integration of management and software engineering concepts within a project management context; topics include general management techniques, models and metrics, case studies and a significant class project.

91-527 Human Factors (3,0)3
Prerequisites: 91-503 and 91-523. An examination of the factors that contribute to well-engineered user interfaces for a wide variety of programs. Consideration of screen design, programming technique, and input devices. Review of human factors literature and analysis of statistical methods used in human factors research.

91-528 Software Engineering for Computer-aided Design (3,0)3
Prerequisites: 91-412 OR 91-523, and 91-503.
Recommended prior background in VSLI Design, DBMS, Graphics. Software design for computer-aided engineering (CAE) workstations. Algorithms for logic simulation, layout, placement, routing,

testing, silicon assembly and compilation, and CAD database management; actual development of CAE tools.

91-529 Introduction to Computer-Aided Design (3,0)3
Prerequisites: 91-503 and 91-523
The design, specification, implementation and testing of CAD applications, including geometric and data-base modeling, integrated multiple system concepts (with CAM and CAE), standards and tools.

91-530 Topics in Software Engineering (3,0)3

91-531 Programming Language Design (3,0)3
Prerequisites: 91-301 or 91.406, and 91.502
Description, structures, and design philosophies of high level programming languages. Design aspects of names and types, data and control structures, and features for data abstraction and modularity. Concepts of functional, logic, object-oriented, concurrent, distributed, and real-time programming languages. A design project is required.

91-534 Compiler Construction I (3,0)3
Prerequisites: 91-301 and 91-503.
This course implements a compiler for a complete language. Topics include LL and LR parsing, parser generators, semantics analysis, code generation including Graham-Gainville code generators, and optimization. Programming project required.

91-535 Compiler Construction II (3,0)3
Prerequisite: 91-534
Continuation of 91-534

91-538 Semantics of Programming Languages (3,0)3
Prerequisite: 91-301 and 91-502
This course covers various semantic models with an emphasis on the Scott-Strachey denotational approach. Project required.

91-539 Computational Logic (3,0)3
Prerequisite: 91-301 and 91-502
Semi-decision procedures for first-order logic and their correctness. Tableaus, unification, and resolution. Horn clauses and logic programming. Selected topics in areas such as nonstandard logics and architectures.

91-540 Topics in Languages and Compilation (3,0)3

91-541 Scientific Visualization (3,0)3
Prerequisite: 91-503
Topics from the current literature. This course looks at classical and novel methodologies for the visualization of large amounts of data. Examples from the medical literature and from other areas of application will be studied in substantial detail.

91-542 Vision and Imaging Systems (3,0)3
Prerequisite: 91-503
Fundamentals of vision. Mathematical techniques for signal processing; continuous and discrete images; binary images; egmentation; edges and edge finding; reflectance map; optical flow; photogrammetry; pattern classification; polyhedral objects; extended Gaussian images. A project will be required.

91-543 Artificial Intelligence (4,0)4
Prerequisites: 91-301 and 91-503.
Search and games, knowledge representation paradigms, natural language understanding, planning, perception. Use of the LISP language for one or more programming projects.

91-544 Advanced Artificial Intelligence (3,0)3
Prerequisite: 91-543.
Topics from the recent literature. Possible topics will be: natural language understanding, program verification, automatic theorem proving, heuristic search, rule based systems, machine learning, perception.

91-545 Knowledge Based Systems (3,0)3
Prerequisite: 91-543.
Rule and non-rule based systems, knowledge acquisition and representation, inference under uncertainty. Well known systems (MYCIN, PROSPECTOR, EL, AM, HEARSAY...) will be examined. Research projects will be assigned.

91-546 Computer Graphics (3,0)3
Prerequisite: 91-503 and 91-515
Introduction to the hardware, software and mathematics of 2- and 3- dimensional interactive computer graphics systems, including standards, modeling, transformations, hidden-surface removal, shading and realism.

91-547 Computer Graphics II (3,0)3
Prerequisite: 91-546.
Lighting models, photorealism, animation, constructive solid geometry and distributed graphics.

91-548 Robotics I (3,0)3
Prerequisite: 91-503 and 91-515
Theory of robotics control, manipulation and vision; current industrial techniques and applications; vision and sensors; factory of the future and productivity.

91-549 Robotics II (3,0)3
Prerequisite: 91-548.
Intelligent manufacturing, expert systems for CAD/CAM, autonomous robots, computer integrated manufacturing, robotic planning and topics in advanced sensors.

91-550 Topics in Graphics, Robotics and Artificial Intelligence (3,0)3

91-551 Computer Architecture (3,0)3
Prerequisites: 91-305 and 91-503.
An advanced study of computer system organization. Topics include data path design, control, ALUs, memory organization, distributed processing, theories of parallel computing, advanced architectures, computer communication.

91-553 Parallel Processing (3,0)3
Prerequisites: 91-515 and 91-551.
Sequent and Intel IPSC will be required.

91-555 Computer Networks (3,0)3
Prerequisite: 91-563.
Primary emphasis of the course shall be on performance analysis of network protocols as well as detailed studies of various protocol layers from existing networks. Topics covered are ISO reference model, IBM SNA, Local Area Networks and ISDN (Integrated services Digital Network).

91-560 Topics in Architecture (3,0)3

91-563 Data Communications I (3,0)3
Prerequisites: 91-503.
Resources sharing; computer traffic characterizations; multiplexing; network structure; packet switching and other switching techniques; design and optimization; protocols; routing and flow control; simulation and measurement; communications processors.

91-564 Data Communications II (3,0)3
Continuation of 91-563. 91-570
Topics in Data Communications

91-573 Data Base I (3,0)3
Prerequisite: 91-503 and 91-515
Study of three database models: hierarchical, network, and relational (including database design). This course also covers integrity, security, concurrency and implementation of a centralized database system.

91-574 Data Base II (3,0)3
Prerequisite: 91-573.
Continuation of Data Base I. In-depth study of data models, null issue, view update, distributed database and database machines. In the second half of the semester, students design a distributed relational database.

91-580 Topics in Database Systems (3,0)3

91-585 Formal Languages and Automata (3,0)3
Prerequisites: 91-502 and 91-503.
Languages, grammars and recognizers; Chomsky hierarchy; finite state machines and regular languages; PDAs and context free languages; context sensitive languages and their recognition; Turing Machines; open and unsolvable problems.

91-586 Theory of Computation (3,0)3
Prerequistites: 91-502 and 91-503.
Examination of models of computation: Turing Machines, Markov algorithms, etc. Recursive function theory; selected topics.

91-587 Computational Algebra (3,0)3
Prerequisites: 91-502 and 91-503.
Construction of software for algebraic problems: linear systems, eigenvalues; singular value decomposition; examination of currently available systems.

91-590 Topics in Computing Theory (3,0)3

91-591 Project (3,0)3

91-592 Directed Study (3,0)3

91-743 Master's Research (3,0)3

91-746 Master's Research (6,0)6

91-749 Master's Research (9,0)9

91-753 Doctoral Research (3,0)3

91-756 Doctoral Research (6,0)6

91-759 Doctoral Research (9,0)9

Department of Mathematics

Department Chairperson: Kenneth M. Levasseur, Associate Professor; B.A., St. Anselm's College; M.S., Ph.D., University of Rhode Island;

Graduate Coordinator: Donald L. Ameen, Associate Professor; B.S., Lowell Technological Institute; M.S. Cornell University.

Faculty: Shimshon Berkovits, Professor; S.B., Massachusetts Institute of Technology; M.S., University of Chicago; Ph.D., Northeastern University; Ronald I Brent, Assistant Professor; B.S., State University of New York at Binghamton; M.S., Ph.D., Rensselaer Polytechnic Institute; Charles L. Byrne, Professor; B.A., Georgetown University; M.A., Ph.D., University of Pittsburgh; Pasquale Condo, Associate Professor; B.S., Purdue University; M.S., Lowell Technological Institute; Alan W. Doerr, Professor; B.A., Marist College; M.A., Hunter College; Enrique Gonzalez-Velasco, Professor; B.S., Ph.D., Polytechnic University of Madrid; Sc.M., Ph.D., Brown University; James Graham-Eagle, Associate Professor; B.S., M.S., Victoria University, Wellington; Ph.D., Oxford University; Dominique Haughton, Assistant Professor; B.S., D.E.A., University of Paris VII, and Ecole Normale Superieure, Ph.D., Massachusetts Institute of Technology; Ann Marie Hurley, Assistant Professor; A.B., Emmanuel College; M.S., University of Lowell; Tom Jyh-Ming Jiang, Assistant Professor; B.S., National Chengchi University; M.A., Ph.D., State University of New York at Albany; Lee K. Jones, Professor; B.S., Tufts University; M.S., Ph.D., Stanford University; Gerald Kaiser, Associate Professor; B.S., Case Institute of Technology; M.S., Carlton University; M.S., Ph.D., University of Wisconsin; Ph.D., University of Toronto; Alan Kaplan, Associate Professor; B.S., University of Massachusetts; M.S., Ph.D., Syracuse University; Yuly Makovoz, Professor; M.S., University of Tchernovtsy; Ph.D., Urals University; Rida M. Mirie, Assistant Professor; B.S., American University of Beirut; M.S., Ph.D., Brown University; Guntram B. Mueller, Associate Professor; B.S., Loyola College (Montreal); M.S., Ph.D., Notre Dame University; Stephen A. Pennell, Associate Professor; B.S., Rensselaer Polytechnic Institute; Sc.M., Ph.D., Brown University; Vidhu Prasad, Associate Professor; B.S., M.S., McGill University; Ph.D., Bryn Mawr College; Shelley L. Rasmussen, Associate Professor; B.S., M.A., Central Michigan University; M.A., Ph.D., University of Michigan; Mary Beth Ruskai, Professor; B.S., Notre Dame College; M.S., Ph.D., University of Wisconsin; Kevin Ryan, Assistant Professor; Sc.B., Ph.D., Brown University; M.S., Cornell University; Alexander Samarov, Professor; B.S., M.S., Moscow State University; Ph.D., Institute for the Problems of Information Transmission, U.S.S.R. Academy of Science; Carolyn Schroeder, Assistant Professor; B.A., M.A., Brandeis University; Ph.D., Massachusetts Institute of Technology; Ashot A. Shaginyan, Associate Professor; M.S., School of Mathematics and Mechanics, State University of Erevan; Ph.D., Steklov Mathematical Institute. Stanley L. Spiegel, Associate Professor; B.S., New York University; A.M., Ph.D., Harvard University; Marvin E. Stick, Associate Professor; B.S., Boston College; M.A., Boston University; Ph.D., Boston College; Virginia S. Taylor, Professor; B.S., Syracuse University; M.A., Western Michigan University; Ph.D., Boston College; Victor Trutzer, Assistant Professor; B.S., M.S., University of Bucharest; Ph.D., Carnegie-Mellon University; I. Jacob Weinberg, Professor; B.S., Yeshiva University; S.M., Ph.D., Massachusetts Institute of Technology; Joyce W. Williams, Associate Professor; B.A., University of Minnesota; M.S., Ph.D., University of Illinois; Yong Q. Yin, Professor; Ph.D., University of Pittsburgh.

Master of Science Degree

There are four options available in this program:

A. Applied Mathematics
B. Scientific Computing
C. Mathematics for Teachers
D. Statistics and Operations Research.

The requirements for admission to each of the options are described in the sections below. All four options require a four-year undergraduate degree in Mathematics, or a related scientific discipline, from an accredited college or university with a satisfactory grade point average, and the official score report of the Aptitude Test of the Graduate Record Examination. Applicants lacking some prerequisites may be accepted as matriculated with conditions. For fall admission, it is recommended that all application materials be received by May 20.

All programs consist of thirty or thirty-three credit hours approved by the Graduate Curriculum Committee. Graduate course offerings from other departments and a maximum of six credit hours at the 400 level may be considered for inclusion in the program of study.

Courses are offered on a regular basis in the late afternoon and early evening so that all programs may be completed on a part-time basis.

A. Applied Mathematics (33 Credit Hours)
The M.S. Option in Applied Mathematics at the University of Lowell focuses on problem solving skills, techniques of mathematical modeling, the fundamental mathematical tools and the computational expertise needed to provide state-of-the-art solutions to modern problems.

There are 6 core courses (18 credits): Applied Math I & II, Numerical Analysis, Numerical Linear Algebra, Real Analysis I, and Complex Analysis I. The remainder of the 33 credits is selected from a list of electives. Graduate courses from other departments, as well as up to 6 credits of 400-level course work, may be considered for inclusion in the program of study. A specific plan of study will be designed in cooperation with the student's faculty advisor.

B. Scientific Computing (30 Credit Hours)
The explosive growth in computer use has brought an ever-increasing demand for trained computer professionals. Many individuals have a scientific background which includes programming experience but have little formal education in computational mathematics. The University of Lowell's Department of Mathematics offers a program in computational mathematics that is specifically tailored to the needs of such students. Specific prerequisites are Calculus (12 credits), differenital equations (3 credits), discrete math (3 credits), probability and statistics (3 credits), and an introductory course in computer science (3 credits).

The program consists of thirty credit hours beyond the prerequisite courses. There are six required core courses (18 credits): Data Structures and Algorithms I & II; Numerical Analysis; Numerical Algebra; Algebraic Structures; and Discrete Mathematics. The remainder of the program is selected with the approval of the Graduate Curriculum Committee from the graduate offerings in Mathematics, Statistics and Computer Science. Upon acceptance to the program, the student must meet with a faculty advisor to formulate an entire plan of study. Subsequent changes to the agreed plan can be made with the advisor's consent.

C. Mathematics for Teachers
(30 Credit Hours)
The Master of Science in Mathematics for Teachers Program aims to give students a balanced combination of theory and practice, to enhance their appreciation and understanding of mathematics as a science, and to provide them with the tools necessary to instill in their own students an interest in the subject.

Courses in Discrete Mathematics, Mathematical Analysis, Linear Algebra, Number Theory, Geometry, and Probability and Statistics are designed to introduce the student to several important areas of mathematics. Courses in Problem Solving, History of Mathematical Science, Mathematical Modeling, and Computers in the Classroom are intended to provide a deeper awareness of the contexts in which mathematical activity takes place and of the mental processes and technological aids employed by people in solving mathematical problems. Students in the program must have access to a personal computer with at least 128K bytes of memory.

Applicants must hold a bachelor's degree from an accredited college or university and have maintained a satisfactory grade point average. They must have completed at least

three semesters of calculus. The Master of Science in Mathematics for Teachers Program consists of the following required three-credit courses, totalling 30 credit hours: Discrete Structures, Mathematical Analysis, Computers in the Classroom, Number Theory, Problem Solving, Linear Algebra, Geometry, History of Mathematical Science, Mathematical Modeling and Probability and Statistics. Students with appropriate backgrounds may replace some of the required courses with alternate courses.

D. Statistics and Operations Research
(30 Credit Hours)
This option is a professionally oriented program that provides the necessary mathematical skills to solve many of the data analysis and optimization problems of government, industry, science, engineering, and management.

All applicants must hold an undergraduate degree with a satisfactory grade point average from an accredited four-year college or university. The degree must be in either mathematics, statistics, operations research, computer science, or a related discpline.

Prerequisites are Calculus (12 credit hours), Linear Algebra (3 credit hours) and Probability and Statistics (6 credit hours; Calculus Based). (The corresponding courses at University of Lowell are 92.131 Calculus I, 92.132 Calculus II, 92.231 Calculus III, 92.221 Linear Algebra I, 92.307 Probability and Mathematical Statistics I and 92.308 Probability and Mathematical Statistics II.).

The program consists of thirty credit hours beyond the prerequisite courses. The core program consists of the following three required courses plus 6 credits hours directed research: Probability Theory, Mathematical Statistics, and Regression Analysis. The six hours of directed research allows the student to complete a project under the direction of a faculty advisor, applying techniques and concepts learned in course work to an applied problem. The student writes a report and gives a talk describing the results of the project. The remainder of the program is selected with the approval of a faculty advisor from the graduate offerings in Mathematics, Statistics, Operations Research, Computer Science, Engineering, Biology and Management. The program is a flexible one; each student will select courses that fit his or her special interests and needs, with the advice and approval of the faculty advisor. Upon acceptance into the program, the student meets with the faculty advisor to formulate a plan of study. Subsequent changes to the agreed plan can, of course, be made with the advisor's consent.

Five Year B.S./M.S. Program

The department has a five year B.S./M.S. program for outstanding undergraduates. See the undergraduate catalog for details.

Course Descriptions

92-500 Discrete Structures (3-0)3
An introduction to discrete mathematics, including combinatorics and graph theory. The necessary background tools in set theory, logic, recursion, relations, and functions are also included.

92-501 Real Analysis I (3-0)3
Real and complex number systems. Sequences and series. Topology of the real line: completeness, compactness, continuity. Differentiability of single variable functions. Sequences and series, including uniform convergence.

92-502 Real Analysis II (3-0)3
Topology of metric spaces, Multivariable functions, derivative as linear maps, Jacobians, inverse and implicit function theorem, Taylor's theorem, introduction to measure theory.

92-503 Mathematical Analysis (3-0)3
Metric spaces: completeness, compactness, connectedness. Continuity. Discontinuities. Uniform convergence. Power series. Differentiation. Integration.

92-505 Discrete Mathematics (3-0)3
Prerequisite: Linear Algebra or Discrete Structures. Basic counting rules, permutations and combinations, recurrence relations. Asymptotic algorithms analysis, NP-completeness, heuristic algorithms. Linear, integer, and dynamic programming. Coding Theory. Applications.

92-507/508 Applied Functional Analysis I, II
(3-0)3, (3-0)3
Vector, metric, normed, Banach and Hilbert spaces. Spectral theory of linear, compact, and unbounded linear operators. Integral and differential equations, approximation theory, and quantum mechanics.

92-510 Computers and Calculators in the Classroom (3-0)3
This course will explore the roles of mainframes, PC's and hand calculators in instruction, examine some of the available software and consider their use in a variety of areas of secondary mathematics, such as algebra, geometry (Euclidean and analytic) probability and statistics and introductory calculus.

92-511 Complex Variables I (3-0)3
Complex numbers, elementary functions and their geometric representation. Differentiation and integration. Power series. Singularities. Entire and meromorphic functions. Periodic functions.

92-512 Complex Variables II (3-0)3
Prerequisite: Real Analysis I.
Differentiation and integration of complex analytic functions. Cauchy's integral theorem and formula. Singularities and Laurent series. Theory of residues and applications. Harmonic functions. Conformal mapping.

92-513 Number Theory (3-0)3
Study of primes, congruences, number-theoretic functions, Diophantine approximation, quadratic forms and quadratic number fields. Additional topics as time permits.

92-516 Pattern Recognition (3-0)3
Prerequisite: Calculus, probability, matrix algebra. Random vectors: Transformations of Random Vectors. Hypothesis Testing: Error Probability; sequential Tests. Supervised Learning. Nearest Neighbor and Parzen Kernel Approach; Feature Extraction.

92-520 Mathematical Problem Solving (3-0)3
The course will focus on four basic factors that determine effective mathematical problem solving: mathematical resources; ability to use heuristics; ability to control the use of resources and heuristics; and the student's beliefs about the use of mathematics to solve problems and about himself or herself as a problem solver. Effective strategies for incorporating problem solving in the curriculum will also be discussed.

92-521/522 Algebraic Structures I,II
(3-0)3, (3-0)3
Properties of rings, groups, fields, polynomials over fields, extension rings and fields, vector spaces, codes, and additional applications.

92-523 Linear Algebra (3-0)3
Sets and maps. Vector spaces and linear maps, the matrix of a linear map, solving systems of equations, scalar products and orthogonality, eigenvalues and applications.

92-527 Geometry (3-0)3
A wide survey of topics related to secondary school geometry: axiomatics systems and Euclidean geometry; constructions in geometry; geometry of vision, perspective and projective geometry; analytic geometry; historical development.

92-529 Differential Geometry (3-0)3
Differential geometry involving curves and surfaces in 3-space. Curvature, torsion, Frenet equations, intrinsic equations, involutes and evolutes.

92-530/531 Applied Mathematics I, II
(3-0)3, (3-0)3
Matrices, vector analysis, divergence, Green's and Stokes' theorem, series solution of differential equations, boundary value problem. Fourier series and integrals. Partial differential equations, separation of variables.

92.535 History of Mathematical Science
(3-0)3
Ancient numeral systems, Babylonian and Egyptian Mathematics, Pythagorean Mathematics, Duplication, Trisection and Quadrature, Euclid's Elements and Greek Mathematics after Euclid, Hindu and Arabian Mathematics, European Mathematics from 500 to 1600, Origins of modern Mathematics, Analytic Geometry, History of Calculus, Transition to the 20th Century, Contemporary perspectives.

92-537 Vector and Tensor Analysis I (3-0)3
The geometry of curves and surfaces, Serre-Frenet formulas, intrinsic equations of a curve, first and second fundamental forms of a surface, divergence, curl, and gradient.

92-538 Vector and Tensor Analysis II (3-0)3
Tensor algebra, covariant and contravariant differentiation and parallel displacement. Applications to differential geometry and selected topics.

92-539 Differential Forms and Their Applications I (3-0)3
Vector calculus; curves and surfaces; differential forms and multilinear maps.

92-540 Differential Forms and Their Applications II (3-0)3
The gradient, curl, and divergence as exterior derivatives; the general Stokes' Theorem; applications to electrodynamics and thermodynamics.

92-541/542 Fourier Analysis and Boundary Value Problems I,II (3-0)3, (3-0)3
Prerequisite: Real Analysis I Fourier series and integrals.
Orthogonal systems and Sturm-Liouville problems. Applications to boundary value problems in rectangular, cylindrical, and spherical coordinates. Distributions and their applications.

92-543 Ordinary Differential Equations (3-0)3
Prerequisite: Real Analysis I Existence, uniqueness, and smoothness of solutions.
The Poincare-Bendixson theory. The neighborhoods of critical points and closed orbits. Liapunov stability. Linear and perturbed linear systems.

92-545/546 Partial Differential Equations I, II (3-0)3, (3-0)3
Introduction to partial differential equations in the plane and space, with engineering applications. Solution of initial- and boundary-value problems. Complex variables and transform theory.

92-547 Integral Equations (3-0)3
Exact, iterative, and numerical solutions of Volterra and Fredholm integral equations, general operators. Symmetric kernels, orthogonal system of functions, and the Hilbert-Schmidt theorem. Applications.

92-548 Mathematics of Signal Processing (3-0)3
Prerequisite: Real Analysis I
Representation of signals: Fourier analysis, fast Fourier transforms, orthogonal expansions. Transformation of signals: linear filters, modulation. Band-limited signals. Sampling. Uncertainty principle.Windows and extrapolation.

92-550 Mathematical Modeling (3-0)3
This course is devoted to studying the application of mathematics to real-life problems from the physical, biological, social, and behavioral sciences. Experience is provided with a wide variety of models (deterministic, stochastic, simulation, continuous, discrete, axiomatic). Computer use in solving problems is encouraged.

92-551 Calculus of Variations (3-0)3
Prerequisite: Real Analysis I
The first variational problem: necessary conditions. Euler's equation. Generalization to dependent and independent variables. Constraints and Lagrange multipliers. Application to dynamics and elasticity. Direct methods.

92-553 Systems Simulation and Modeling (3-0)3
Prerequisite: Knowledge of FORTRAN and Assembly Language. Procedures in model construction and computerized simulation, modeling tools and techniques, model conceptualization and implementation, selected applications of simulation.

92-560 Data Structures and Algorithms I (3-0)3
Prerequisite: Discrete Structures and Introduction to Data Structures. Implementations of lists, stacks, queues, ordered and binary trees, and priority queues. Tree traversals. Open and closed hashing. Directed graphs: shortest paths and acyclicity.

92-563 Numerical Analysis (3-0)3
Prerequisite: Real Analysis I
Non-linear equations in one and several variables. Numerical differentiation and integration. Numerical methods for ordinary differential equations and for the Laplace, heat, and wave equations.

92-564 Numerical Algebra (3-0)3
Solution of linear systems. Eigenvalue, eigenvector problem. Fast Fourier Transform. Introduction to finite elements. Least squares. Splines, Chebyshev approximation.

92-565 Formal Languages (3-0)3
Principles of finite automata. Properties of languages accepted by finite automata. Context-free grammars and push-down automata. Turing machines and computability.

92-566 Theory of Computation (3-0)3
Prerequisite: PASCAL computability, undecidability, complexity.
Turing machines and the halting problem. Elementary recursion theory. The Church-Turing thesis. Measures of complexity, the speed-up theorem. Proving theorems about programs.

92-570 Probability and Statistics (3-0)3
Overview of descriptive statistics, data analysis, probability of events, discrete random variables, continuous random variables, normal, binomial and other probability distributions, central limit theorem, survey sampling, estimation, hypothesis testing, regression, experimental design, analysis of categorical data, nonparametric statistics.

92-571 Linear Optimization (3-0)3
Simplex and revised simplex methods, duality, sensitivity analysis, the transportation problem and other applications, degeneracy procedures, computational techniques. Introduction to integer programming.

92-572 Non-Linear Optimization (3-0)3
Unconstrained optimization, Lagrange multipliers, Kuhn-Tucker theory, quadratic programming, convex programming, numerical methods.

92-575 Data Structures and Algorithms II (3-0)3
Prerequisite: Data Structures and Algorithms I.
Divide and conquer, radix and comparsion sorts, order statistics, union-find, balanced trees, graph connectivity, path finding, matrix multiplication, fast Fourier transform, pattern matching, NP- completeness.

92-579 Reliability and Life Data Analysis (3-0)3
Prerequisite: Probability or Statistics for Engineering and Science
Introduces statistical methods for analyzing data obtained from lifetime testing of products. Statistical failure models, testing reliability hypotheses and accelerated life testing.

92-580 Combinatorics (3-0)3
Prerequisite: Calculus and Discrete Mathematics. Generating functions, recurrence relations, inclusion-exclusion, Polya theory. Experimental designs (block design). Partially ordered sets. Applications.

92-581 Graph Theory (3-0)3
Prerequisite: Linear Algebra or Discrete Structures. Terminology, theorems, algorithms, and applications of graph theory. Trees, circuits, and connectivity. Hamiltonian and Eulerian graphs. Shortest routes, matching, network flows. Covering, coloring, Ramsey theory.

92-582 Time Series Analysis (3-0)3
Prerequisite: Permission of the instructor.
Building models for discrete time series, and their use in forecasting and control. Stationary and nonstationary time series models. Box-Jenkins (ARMA) and other techniques.

92-583 Cryptography (3-0)3
Prerequisite: Permission of instructor.
Basic concepts; some classical cryptographic examples; modern encryption algorithms, the Data Encryption Standard (DES), public key systems, probabilistic encryption; aspects of key management and inference controls in statistical data bases.

92-584 Stochastic Processes (3-0)3
Prerequisite: Probability or Mathematical Statistics I.
Markov chains and processes, random walks, stationary, independent increments, and Poisson processes. Ergodicity. Examples (e.g., diffusion, queuing theory, etc.).

92-585 Queueing Theory (3-0)3
Prerequisite: Statistics and Probability
Single-server queueing systems, queue length, and waiting time. Multi-server queueing systems. Modeling of telephone systems, interactive computer systems.

92-586 Coding Theory (3-0)3
Prerequisite: Discrete Structures
Error correcting and decoding. Applications to data processing, transmission and security. Linear block, cyclic, convolution and arithmetic codes. Applications from communications and computer science.

92-587/588 Probability Theory and Mathematical Statistics (3-0)3, (3-0)3
Random variables, densities, joint and conditional distributions, expectations, variance, estimation, sufficiency and completeness, hypothesis testing, limiting distributions.

92-589 Theory and Methods of Sampling From Finite Populations (3-0)3
Simple random sampling, systematic sampling, stratified random sampling, multistage cluster sampling, regression estimation, ratio estimation, effect of costs on sample allocation and nonsampling errors.

92-590 Statistical Quality Control (3-0)3
Prerequisite: Probability or Statistics for Engineering and Science
Introduction to statistical methods useful in quality assurance. Description of control charts for attributes and variables, process-capability analysis and acceptance sampling.

92-591 Regression Analysis (3-0)3
Prerequisite: Probability, Biostatistics, or Statistics for Engineering and Science.
Model building via linear regression. Method of least squares, theory and practice. Checking for adequacy of a model, examination of residuals, checking outliers. Experience on real data sets.

92-592 Multivariate Statistical Modeling (3-0)3
Nonlinear model building via least squares. Discriminant and factor analysis, principal components, profile analysis, canonical correlation, cluster analysis. Experience on real data sets.

92-593 Experimental Design (3-0)3
How to design, carry out, and analyze experiments. Randomized block designs, randomization, blocking, matching, analysis of variance and covariance, control of extraneous variables.

92-594 Control Theory (3-0)3
Prerequisite: Real Analysis I
Analytical and numerical methods for optimization of deterministic and stochastic dynamic systems.

92-595 Information Theory (3-0)3
Prerequisite: Real Analysis I
Shannon theory including information measure and transmission rates and capacities. Elements of coding theory.

92-596 Finite Element Methods (3-0)3
Prerequisite: Real Analysis I
Mathematical formulations and techniques including an introduction to variational methods. Examples from solid mechanics, heat transfer, and fluid mechanics.

92-597 Probabilty and Mathematical Statistics (3-0)3
Prerequisite: Real Analysis I
Elementary introduction: combinatorics, geometric probabilities, algebra of probabilities, random variables, classic distributions. Measure-theoretic axiomatics. Analytical methods. Limit theorems. Statistical methods: sampling, estimation, regression and correlation.

92-599 Approximation Theory (3-0)3
Prerequisite: Real Analysis I
Uniform approximation by polynomials. The Weierstrass and Jackson theorems. Characterization of best approximation. Least squares approximation. Approximation by splines and rational functions.

92-651/652 Directed Studies I, II (3-0)3, (3-0)3
Prerequisite: Permission of instructor
This course is intended to satisfy individual student needs. Topics include various fields of mathematics.

92-653/660 Selected Topics I, II (3-0)3
Prerequisite: Permission of instructor
Advanced topics in various fields of mathematics and related fields. Coverage varies from term to term.

92-743, 6 Thesis Research 3, 6

Department of Physics and Applied Physics

Department Chairperson: Aram S. Karakashian, Professor; B.S., M.S., Temple University; Ph.D., University of Maryland.
Graduate Coordinator: James J. Egan, Professor; B.A., Thomas More College; M.S., Ph.D., University of Kentucky.
Faculty: Albert Altman, Professor; B.S., Brooklyn College; M.S., Ph.D., University of Maryland; Leon E. Beghian, Professor and Associate Vice President for Academic Affairs; B.A., D. Phil., University of Oxford; Sergey Broude, Assistant Professor; B.S., Moscow Institute of Physics and Technology; M.S., Ph.D., Academy of Science, Moscow; George E. Chabot, Associate Professor; A.B., Harvard University; M.S., Harvard School of Public Health, Ph.D. University of Lowell, (C.H.P.); Gus Couchell, Professor; B.S., M.S., North Carolina State University; Ph.D., Columbia University; Clayton S. French Jr., Assistant Professor; B.S. Lowell Technological Institute; M.S. PH.D. University of Lowell, (C.H.P.); Zoltan Fried, Professor; B.S., Brooklyn College; Ph.D., Brandeis University. Padmanabh Harihar, Associate Professor; B.Sc., R. Ruia College; M.Sc., Wilson College, India, Ph.D., Columbia University; Jesse Y. Harris, Professor; B.S.,M.S., Ph.D., Rutgers-The State University; Lloyd Kannenberg, Professor; S.B., Massachusetts Institute of Technology; M.S., University of Florida; Ph.D., Northeastern University; Gunter H.R. Kegel, Professor; B.Fis., Universidade de Brasil; Ph.D., Massachusetts Institute of Technology; Jayant Kumar, Assistant Professor; B.Sc., Indian Institute of Technology; Ph.D., Rutgers - The State University; David M. Larsen, Associate Professor; S.B., Ph.D., Massachusetts Institute of Technology; Anthony Liuzzi, Professor; B.S., Rensselaer Polytechnic Institute; M.S., Ph.D., New York University, (C.H.P.); Thomas V. Marcella, Associate Professor; B.S., Lowell Technological Institute; M.S., Northwestern University; Ph.D., Boston College; Suresh C. Mathur, Professor and Assistant to the Vice-President, Planning and Budget; B.Sc., University of Lucknow; Ph.D., University of Texas; Roger D. McLeod, Associate Professor; B.A., Bowdoin College, M.S., Lowell Technological Institute; Walter K. Mellen, Associate Professor; S.B., Massachusetts Institute of Technology; M.S., Lowell Technological Institute; Arthur Mittler, Professor; B.A., Drew University; M.S., Ph.D., University of Kentucky; David J. Pullen, Professor; B.Sc., University of London; D.Phil., University of Oxford; Paul J. Ring, Associate Professor; B.S., Boston College; M.S. Rensselaer Polytechnic Institute; Ph.D., Brown University. Alexander Sachs, Associate Professor; B.S. Northwestern University; Ph.D. University of New Hampshire; Walter A. Schier, Professor; B.S., Saint Procopius College; Ph.D., University of Notre Dame; Kunnat Sebastian, Professor; B.S., M.S., Kerala University; Ph.D., University of Maryland; Eric Sheldon, Professor; B.Sc., (Gen) and B.Sc., (Special Honors), D.Sc., D. Phil., University of London; Kenneth W. Skrable, Professor; B.S., Moravian College; M.S., Vanderbilt University; Ph.D., Rutgers-The State University, (C.H.P.); Richard W. Stimets, Professor; B.S., Ph.D., Massachusetts Institute of Technology; Ye Yung Teng, Professor; B.S., National Taiwan University, China; M.S., Ph.D., University of Maryland. Jerry Waldman, Professor; B.A., M.A., Columbia University; Ph.D., Massachusetts Institute of Technology; Martin Wilner, Professor; B.S., Rensselaer Polytechnic Institute; M.S., Yale University; Ph.D., Massachusetts Institute of Technology; Chuen Wong, Associate Professor; Diploma of Science, Chung Chi College, Hong Kong; Ph.D., Case Western Reserve University.

Physics and Applied Physics

Research Programs

Members of the Department are engaged in research programs in the following areas in which opportunities for advanced degree research are offered: Theoretical and Experimental Nuclear Physics, Theoretical and Experimental Solid State Physics, Laser Physics, Optics, Theory of Elementary Particles, Quantum Field Theory, Atomic Physics, Relativity, Atmospheric Physics, Biophysics, Nuclear and Solar Energy, Applied Mechanics, Computational Physics, Radiological Sciences and Medical Physics.

Research facilities are housed at the Radiation Laboratory, the Olney Science Center, and the University of Lowell Research Foundation. Research equipment at the Radiation Laboratory includes an 800 kilocurie 60 Co source, a 5.5 MV Van de Graaff accelerator, a one-megawatt nuclear reactor, two Hewlett-Packard System 1000 computers, a neutron time-of-flight spectrometer, a fast neutron irradiation facility, a helium-jet fission fragment transfer system, a thin film evaporator, a Rutherford backscattering spectrometer for materials characterization, digital and analog oscilloscopes and other instruments. Laboratory equipment in the Olney Science Center and the Research Foundation includes a diffusion furnace, two thin film evaporators, Fourier transform and ATR spectrometers, a scanning monochromator, dye, infrared, and far infrared lasers, microelectronics laboratory, a superconducting magnets, scanning electron microscope, a 2 MV Van de Graaff accelerator, and several mini computers and personal computers. The University Computer Center has a VAX computer available for research use.

Entering Graduate Students

Every entering graduate student is assigned a departmental adviser who will counsel the

student on programs of study and other academic requirements, serve as registration officer, help the student to become acquainted with research opportunities in the Department, and assist in selecting a research supervisor.

Applicants must submit the official test score report for the GRE general test; the subject test is not required. Applicants for the M.S. and Ph.D. degrees in Physics are expected to have a sound background in intermediate level mechanics, electricity and magnetism, quantum mechanics, and modern physics. Any student found deficient in any of these areas may be required to take appropriate courses to remove the deficiency.

Students in the Radiological Sciences and Protection M.S. program should have adequate preparation in mathematics, chemistry, physics, biology and nuclear and radiological sciences similar to the undergradute curriculum in Radiological Health Physics at the University of Lowell.

Master of Science Degree Program

The Department of Physics and Applied Physics offers Master of Science degrees in Physics and in Radiological Sciences and Protection. The master's program in Physics provides an opportunity for advanced study and research in most of the areas mentioned above, including a M.S. option in Optical Sciences. The master's program in Radiological Sciences and Protection is described elsewhere in this catalog.

Graduate Credits and Course Requirements

At least 30 graduate credit hours are required, of which at least 6 and at most 12 are to be M.S. Thesis Research, or, if a M.S. project is approved by the Department in place of a master's thesis, a maximum of 3 credits of M.S. project research will be allowed. At most, 3 credits of Physics Colloquium and seminar courses may be applied to the 30 credit requirement.

Candidates for the Master of Science degree in Physics, except those in the Optical Sciences Concentration, are required to complete the following courses:

		Credits
95-605	Mathematical Methods of Physics I	4
95-611	Classical Mechanics	3
95-615	Quantum Mechanics I	4
	and either	
95-606	Mathematical Methods of Physics II	4
	or	
95-616	Quantum Mechanics II	4
95-711/712	Graduate Seminar in Physics	1
95-701/702	Physics Colloquium	1
	Thesis	6-12
	or Project	3
	Electives	

Electives may be chosen from the list of courses acceptable for graduate credit in Physics. Some graduate courses offered by other departments may also be acceptable for graduate credit in Physics, with the approval of the Physics Department.

Optical Sciences Option

This program is designed to provide the necessary preparation for students wishing to specialize in such rapidly expanding fields as electro-optical phenomena, lasers, applications of optics to telecommunications and information processing, fiber optics and other new optical materials and devices. This option is intended for students who have completed a bachelor's degree program in Physics, Engineering, or other sciences. It is offered in cooperation with the Department of Electrical Engineering, which offers an allied option in Opto-electronics. The Optical Sciences option emphasizes laboratory research providing the student valuable "hands-on" experience with optical systems and devices. Two course sequences are available (1) for students with a B.S. in Physics; and (2) for students with a B.S. in Engineering or another scientific discipline.

Course requirements for the Optical Sciences Concentration For Students with a Physics B.S.

		Credits
95-605	Math. Meth. Phys. I	4
80-547	Laser Physics and App.	3
80-539	Electro-Optics	3
96-539	Electro-Optics Lab	2
	Seminars and Colloquium	3
	Thesis	6-12
	or Project	3
	Electives	

For Students with B.S. in other Sciences or Engineering*

		Credits
95-605	Math. Meth. Phys. I	4
80-547	Laser Physics and App.	3
80-539	Electro-Optics	3
96-539	Electro-Optics Lab	2
80-555	Physics of Rad. and Nuc.	3
80-536	Applied Quantum Mech	4
	Seminars and Colloquium	3
	Thesis	6-12
	or Project Electives	3

Electives must be choosen from the following list of courses:

		Credits
80-551	Fiber Optics & Lab	4
80-540	Image Processing & Lab	4
95-572	Solid State Physics	3
95-615	Quant. Mech I	4
16-658	Electro-Optic Design	3
16-720	Optics for Information Proc.	3

* Assuming adequate preparation in mathematics and electromagnetism.

Colloquia

All full-time master's candidates are required to attend Physics Colloquium, 95-701/702, each semester.

Seminars

All full-time master's candidates are required to take 95.711/712 Graduate Seminar in Physics, in addition to the Colloquium each semester. After a student has presented a seminar in 95.711/712 he or she may substitute one of the other seminars offered by the Department.

Thesis or Project

The thesis or project is to be based on research performed under the supervision of a member or associate of the graduate faculty. A student may do a thesis under the supervision of a faculty member in another department provided he or she has a member of the Physics Graduate Faculty as a co-supervisor. The student must submit to the Department, for its approval, eleven copies of a typewritten proposal briefly describing the project or the problem to be solved for the thesis. This proposal must bear the written approval of the research supervisor. A student may not register for M.S. Thesis Research, or M.S. Project Research until the proposal has been approved. Students registered for Thesis must submit a brief progress report on the research to the Graduate Coordinator each semester unless a thesis is submitted.

Students registered for project research must submit a final report and complete an oral defense of the project before the end of the semester. An M.S. project may not be carried over into a second semester.

After completing the work, thesis students must submit three copies of a typewritten thesis to the Department. The student must then pass an oral examination, administered by a Thesis Committee of the Department appointed by the Graduate Coordinator. The examination will be based up on, but not necessarily restricted to, the subject of the thesis. A student who elects a project rather than a thesis must submit three copies of the project report to the Department and pass an oral examination based upon the subject of the project and upon the subjects all physics M.S.candidates are expected to know. (i.e. the subjects in the recommended M.S. course sequence.)

Doctor of Philosophy Degree Program

The Doctor of Philosophy program in Physics and Applied Physics is designed to develop advanced competence in Physics. The Physics

Concentration prepares the student to carry out original and independent research in physics, while the Applied Physics Concentration provides training for professional work in several areas of applied physics and allied engineering disciplines.

Graduate Credits

At least 60 graduate credit hours are required, of which at least 15 and at most 24 are to be Ph.D. Dissertation Research. At most 3 credits of Physics Colloquium and seminar courses may be applied to the 60 credit requirement.

Colloquia

All full-time doctoral candidates are required to attend Physics Colloquium, 95-701/702, each semester.

Seminars

All full-time doctoral candidates are required to take at least one physics seminar, in addition to Colloquium, each semester. After a student has presented a seminar in 95-711/712 he or she may substitute one of the other seminars offered by the Department.

Foreign Language

All candidates are required to demonstrate at least journal level (Level 2) proficiency in French, German or Russian by passing the Ph.D. Foreign Language Examination administered by the Phyics Department. This exam requires the scientifically accurate translation of an article in French, German, or Russian into good English with the aid of a dictionary.

Other Skills

All candidates are required either (a) to demonstrate at least journal level proficiency in a second foreign language from among French, German or Russian or (b) to demonstrate proficiency in computer programming, which may be accomplished by passing the departmental computer language exam or by achieving a grade of at least B in courses such as FORTRAN Programming or Introduction to Pascal, or by demonstrating equivalent competence to the Physics Department.

Comprehensive Examination

All candidates must pass a written and oral Physics Comprehensive Examination. Students in the Physics concentration are expected to take this examination in their first year; those in the Applied Physics concentration, in their second year. The examination covers I. classical mechanics, II. electricity and magnetism, and III. quantum mechanics and modern physics at the advanced undergraduate level. Part III is replaced by a section on radiological sciences and protection for students in that option and is based on the advanced undergraduate course requirements in Radiological Health Physics.

Graduate Research Admission Examination

Before commencing Ph.D. dissertation research each doctoral candidate must pass two semesters of Advanced Projects in Physics 96.751/752 and defend this project in an oral examination before a committee of the Physics graduate faculty. Students who have already completed a master's thesis in Physics or a related discipline may apply for a waiver of the Advanced Projects requirement. However, if the M.S. degree is from another institution the student must make an oral presentation of the M.S. work before a committee of the Physics graduate faculty in order to satisfy the Graduate Research Admission Examination requirement. The Graduate Research Admission Examination must be passed before a student may submit a Ph.D. dissertation proposal.

Dissertation

The dissertation is to be based upon original research performed under the supervision of a member or associate of the Physics Graduate Faculty (or the Graduate Faculty of a Department participating in a joint program with the Physics Department) holding an earned doctoral degree. If a student wishes to do a dissertation under the supervision of a faculty member in another department, the student must also have a co-supervisor who is a member of the Physics Graduate Faculty. Ph.D. candidates must submit to the Department, for its approval, eleven copies of a typewritten proposal briefly describing the research to be carried out. The proposal must bear the written approval of the research supervisor. A student may not register for Ph.D. Dissertation Research until the Comprehensive Examination and the Graduate Research Admission Examination have been passed and the dissertation proposal has been approved. After completing the work, the student must submit four copies of a typewritten dissertation to the Department. The student must then pass an oral examination, administered by a Dissertation Committee appointed by the Physics Graduate Coordinator, based on, but not necessarily limited, to the dissertation research.

The Physics Concentration

The following courses are required:

95-605/606	Mathematical Methods of Physics I, II	(4-0)(4-0)8
95-611	Classical Mechanics	(3-0)3
95-615/616	Quantum Mechanics I,II	(4-0)(4-0)8
95-657/658	Electromagnetic Theory I, II	(4-0)(4-0)8
95-617	Advanced Quantum Mechanics I	(3-0)3
96-751/752*	Advanced Projects in Physics I, II	(3-0)(3-0)6

* This requirement may be waived for students who have written a master's thesis in Physics or a related discipline.

Electives may be chosen from the list of courses acceptable for graduate credit in Physics. Some graduate courses offered by other departments may also be acceptable for graduate credit in physics, but only with the approval of the Physics Department.

The Applied Phyics Concentration

Students in the Applied Physics Concentration may select a program of study and research in one of the following areas:

1. Physics/Energy Engineering Option
   (a) Nuclear Energy
   (b) Solar Energy
2. Physics/Applied Mechanics Option
3. Physics/Radiological Sciences Option
4. Solid State-Optics Option

Areas 1, 2, and 3 are degree options and will be so noted on the diploma. Areas 1 and 2 are interdisciplinary programs with the Department of Chemical and Nuclear Engineering and with the Department of Mechanical Engineering, respectively. Area 3 is an extension of the Master of Science degree program in Radiological Sciences and Protection. Area 4 involves the development of novel solid state electro-optic, acousto-optic and photovoltaic devices.

General Required Courses

Every student in the Applied Physics Ph.D. Concentration must satisfy the following course requirements:

(a)

95-513	Classical Mechanics	(4-0)4
95-553/554	Electromagnetism I, II	(3-0)(3-0)6
95-535/536	Intro Quantum Mechanics I, II	(3-0)(3-0)6
95-605/606	Mathematical Methods of Physics I, II	(4-0)(4-0)8

(b) Six or eight credits from among the following courses, or their equivalents, as appropriate for each particular area of concentration:

95-611	Classical Mechanics	(3-0)3
95-521	Statistical Thermodynamics	(4-0)4
95-561/662	Nuclear Physics I,II	(3-0)(3-0)6
95-615/616	Quantum Mechanics I,II	(4-0)(4-0)8
95-617/618	Advanced Quantum Mechanics I,II	(3-0)(3-0)6
95-657/658	Electromagnetic Theory I,II	(4-0)(4-0)8
95-660	Quantum Mechanics of Many Particle Systems	(3-0)3

(c) 96-751/752 Advanced Projects in Physics I,II (3-0)(3-0)6

or the equivalent in the department appropriate to the student's chosen field of concentration. This may be waived for students who have completed a master's thesis.

Physics/Energy Engineering

In addition to the general requirements, students in this option must take at least seven additional courses from among the Physics, Energy Engineering, and Mechanical Engineering offerings at the graduate level. These seven courses should include required courses appropriate to either the Solar or Nuclear energy specialization.

Applied Mechanics

In addition to the general requirements, students in this option must take at least two graduate courses from the Mechanical Engineering Department, the courses to be determined by the student's academic and research advisors.

Radiological Sciences

In addition to the general requirements, students in this option must take the following courses:

95-561/662 Nuclear Physics I, II (3-0)(3-0)6

and at least twelve credits from among the following graduate level Radiological Sciences and Protection courses, assuming the core courses for the Master of Science Degree in Radiological Sciences and Protection have already been completed.

98-522	Envir Radiation & Nuc Site Criteria	(3-0)3
98-561/2	Special Topics in Radiological Sciences	(3-0)3
98-563	Intro to Radiation Chemistry	(3-0)3
98-608	Environmental Toxicology & Epidemiology	(3-0)3
98-613	Environmental Monitoring & Surveillance	(3-0)3
98-614	External Radiation Dosimetry	(3-0)3
98-615	Internal Radiation Dosimetry	(3-0)3
98-616	Data Reduction for Rad. Sci. & Prot.	(3-0)3
98-620	Environmental Impact Statements	(3-0)3
98-625	Medical Health Physics	(3-0)3
98-646	Accelerator Health Physics	(3-0)3
98-651	Intro to Electronic Product Radiation	(3-0)3
98-666	Reactor Health Physics	(3-0)3
98-681	Medical Physics	(3-0)3
98-682	Medical Physics Laboratory	(0-9)3

NOTE: It is expected that the requirements for the Master of Science degree in Radiological Sciences and Protection will be met during the first four semesters if the student has not already earned an M.S. degree.

Solid State-Optics

In addition to the general requirements, students in this area must take the following courses:

95-572	Solid State Physics	(3-0)3
95-705/706	Seminar in Solid State-Optics	(1-0)(1-0)2
80-539	Electro-Optics	(3-0)3
96-589	Electro-optics Lab	(0-3)2
80-547	Laser Physics and Applications	(3-0)3
80-551	Fiber Optics	(2-3)4

and may choose electives from among courses offered by other departments, subject to the approval of the Physics Department.

Course Descriptions

In the following listings course numbers with prefix 80 are Applied Physics courses, those with prefix 95 are Physics courses and those with prefix 96 are laboratory courses or research credit courses.

80-506 Nuclear Instrumentation II (2-4)4
Prerequisite: 80-355/555, 24-535
Operating principles and applications of nuclear radiation detectors, associated electronic signal processing equipment, data analysis techniques. Topics covered include charged-particle, photon, and neutron detection, plus charged-particle and gamma-ray spectroscopy. Use of scintillators, photomultiplier tubes, solid state detectors, gas-filled counters, oscilloscopes, etc.

80-539 Electro-Optics (3-0)3
Prerequisite: 80-338 and 96.539 corequisite
Optical properties of materials, including dispersion, absorption, and anisotropy. Blackbody radiation, emission spectra, incoherent radiators, and lasers. Photoeffect, semiconductor detectors, photochemistry, and applications to various detectors.

80-540 Image Processing (2-3)4
Prerequisities: 80-238, 80-338
Basic physics of television and other imaging systems: representation and manipulation of images in digital form; Fourier analysis and filtering of images: detection of image features such as edges and regions, pattern recognition, three-dimensional visual perception in man and machine, examples of image processing tasks from such areas as medicine, industrial inspection and robotics, laboratory exercises with an image processing system utilizing an Octec 2000 image analyzer and a Data General Nova 4/C Computer. Ability to program a computer is required.

80-547 Laser Physics and Applications (3-0)3
Prerequisite: 95-335/535
Spontaneous and stimulated emission line broadening processing, rate equations, laser oscillation condition, spectral output of lasers. Gaussian beam propagation and resonator design parameters. Key features of ultraviolet through far infrared laser systems. Application to spectroscopy, radar, welding.

80-551 Fiber Optics (2-3)4
Prerequisite: Permission of instructor
Introduction to optical communications; basic theory of light guiding; propagation characteristics and focussing effect of an optical waveguide; optical sources and detectors for fiber communications; fundamental parameters of optical fibers, fabrication and testing methods for optical fibers.

80-631 Non-linear Optics (3-0)3
Brief review of linear optics and optical waves in anisotropic linear media. Wave propagation in nonlinear media. Acousto-optics. Second order nonlinear optical phenomena: sum and difference frequency generation, parametric amplification, Pockets effect and electro-optic modulators based on them. Third order nonlinear optical phenomena: third harmonic generation, stimulated Raman scattering, stimulated Brillouin scattering, intensity dependent refractive index and Kerr effect. Magneto-optical phenomena and the physics of photorefractive materials.

80-686 Semiconductor Physics (3-0)3
Prerequisite: 95-472/572
Transport and optical properties of semiconductors. Statistics, collision mechanisms, effective mass theory, donors and acceptors. Hot electrons. High magnetic field phenomena. Devices: junctions and transistors. Gunn oscillators; semiconductor lasers.

95-513 Mechanics (4-0)4
Prerequisite: 80-208 or equivalent
Coordinate transformations and vectors; motion in one and three demensions; oscillators: linear and non-linear and driven; non-inertial frames, central forces, collisions, planar motion of rigid bodies in two and three dimensions. Center of mass and moment of inertia.

95-521 Statistical Thermodynamics (4-0)4
Prerequisite: 95-335/535 or permission of instructor
First and second laws of thermodynamics, statistical definition of entropy, definition of absolute temperature, thermal equilibrium of a system in a heat bath; canonical partition function and its applications; thermodynamic potentials; third law of thermodynamics, Carnot cycle, heat engines and refrigerators, phase equilibria and the Clausius-Clapeyron equation and its applications; the heat capacity of solids; Einstein's and Debye's models; blackbody radiation and Planck's law for spectral distribution; grand canonical partition function; Bose-Einstein and Fermi-Dirac distributions for ideal gases; the classical perfect gas; ideal Fermi gas and conduction electrons in metals; ideal Bose gas and Bose-Einstein condensation; superfluidity of He II.

95-535 Introductory Quantum Mechanics I (3-0)3
Prerequisite: 95-210 or equivalent
De Broglie waves, the Schroedinger equation, wave functions, wave packets, Heisenberg uncertainty principle, expection values, particle in a box, the simple harmonic oscillator, free particles, step barrier, barrier penetration, square well potential.

95-536 Introductory Quantum Mechanics II (3-0)3
Prerequisite: 95-335/535
The three dimensional Schroedinger equation, the deuteron, angular momentum, spin, the hydrogen

atom, spin-orbit interaction, Zeeman effect, Pauli exclusion principle, atomic structure, spectroscopic nomenclature, molecular structure, perturbation theory, transition rates, and scattering theory.

95-553 Electromagnetism I (3-0)3
Prerequisite: 80-208, 95-210 or equivalent
The theory of electromagnetic fields using vector analysis, electrostatic fields and potentials in vacuum, conductors, and dielectric media, electric multipoles, solutions to Laplace's equation, boundary conditions, image charge problems, magnetic effects of steady currents in nonmagnetic media.

95-554 Electromagnetism II (3-0)3
Prerequisite: 95-553
Magnetic induction and time varying currents and fields, magnetic materials, Maxwell's equations, propagation of electromagnetic waves in vacuum, conductors and dielectrics, reflection and refraction of electromagnetic waves, radiation from dipoles and antennas.

95-561 Nuclear Physics I (3-0)3
Prerequisite: 95-336/536 and 95-354/554
Nuclear charge radius, mass, binding energy, moments, parity and statistics; nuclear barrier penetration and theory of alpha decay and fission; theory of beta and gamma decay and selection rules.

95-572 Solid State Physics (3-0)3
Prerequisite: 95-421/521
Crystal structures, x-ray and neutron diffraction, lattice vibrations, the free electron and the band models of metals, semiconductors and applications, dielectric and optical properties of solids, magnetism and superconductivity.

95-605/606 Mathematical Methods of Physics I, II (4-0)(4-0)8
Prerequisite: Permission of Instructor
Vector and Cartesian tensor analysis; matrices and determinants; partial differential equations, boundary value problems and special functions. Numerical analysis and applications; theory of analytic functions; Green's functions.

95-607 Lie Algebras in Particle Physics (3-0)3
Prerequisite: 95-616
Introduction to group theory and its application to high energy physics; definition of a group and its representations; Lie groups and Lie algebras; study of SU(2) Lie algebra, its representations and the Wigner-Eckart theorem; isospin group; roots, weights and simple roots of simple Lie algebras and applications to the SU(3) group; tensor methods for Lie algebras; SU(3) flavor symmetry; Young Tableaux for decomposing products of representations; SU(N) group; SU(6) and the Quark model; the color SU(3) group and the theory of strong interaction of quarks; hadron mass; splittings using group theory; grand unification and the SU(5) group.

95-608 Introduction to Particle Physics (3-0)3
Prerequisites:95-607 and 95-617
Introduction to quark models; unified gauge theory of weak and e.m. interactions; weak decays of leptons and hadrons; quantum chromodynamics and strong interactions of quarks and gluons; asymptotic freedom; the bound states of quarkonia; the E1 and M1 transitions in quarkonia.

95-611 Classical Mechanics (3-0)3
Prerequisite: 95-513
Review of fundamental principles of mechanics. Central force motion and stability problems. Lagrangian formulation, including Hamilton's principle; Lagrange multipliers. Coupled harmonic oscillators, normal modes. Hamiltonian formulation: Hamilton's equations, finite and infinitesimal canonical transformations, Hamilton - Jacobi method, Poisson brackets, connections among conserved quantities, symmetries and canonical invariants.

95-615/616 Quantum Mechanics I, II
(3-0)(3-0)6
Prerequisite: 95-611 concurrently
Wave packets and free particle motion, the wave function and the Schroedinger equation, the linear harmonic oscillator, the WKB approximation, central forces and angular momentum, spin, and time-dependent and time-independent perturbation theory, scattering theory.

95-617 Advanced Quantum Mechanics I
(3-0)3
Prerequisite: 95-616
Dirac equation as a single particle wave equation, free particle spinors and plane waves, matrices and relativistic covariance, nonrelativistic approximation and the fine-structure of the H atom. Quantization of the e.m. field in the coulomb gauge; interaction of an atom with the quantized radiation field; radiative transitions in atoms; Thomson scattering; classical and quantized Lagrangian field theory; Symmetries and conservation laws; quantization of the real and complex Klein-Gordon field; Dirac Field and the covariant quantization of the e.m. field; Feynman propagators; the interaction picture and the S-matrix expansion in perturbation theory and the Wick's Rule. Feynman diagrams and rules for calculating S-matrix elements in QED; formulas for cross-section and spin and photon polarization sums; calculation of cross-sections for (1) $e^+ + e^- \rightarrow l^+ + l^-$ (2) $e^+ + e^- \rightarrow e^+ + e^-$ (3) Compton scattering and (4) scattering of electrons by an external e.m. field.

95-618 Advanced Quantum Mechanics II
(3-0)3
Prerequisite: 95-617
Radiative corrections to processes in quantum electrodynamics; mass and charge renormalization; dimensional regularization; vacuum polarization; anomalous magnetic moment of the electron and the Lamb-shift; unified gauge theory of electro-weak interactions; W and Z bosons and their properties; introduction to quantum chromodynamics.

95-631 Integrated Optics (3-0)3
Prerequisite: Permission of Instructor
Planar optical waveguide modes. Wave guide fabrication methods. Losses in optical wave guides. Input and output couplers. Coupling between wave guides. Electro-optics and acousto-optic modulators. Semi-conductor lasers and detectors.

95-657/658 Electromagnetic Theory I, II
(4-0) (4-0)8
Prerequisite: 95-606
Electrostatics and magnetostatics with special attention to boundary value problems. Quasistatic fields and displacement currents. Maxwell's equations, special relativity, waveguides, scattering, radiation from accelerated charges, propagation in material media and plasmas, Kramers-Kronig relations.

95-660 Quantum Mechanics of Many Particle Systems (3-0)3
Prerequisite: 95-616
Non-relativistic quantum mechanics of many-particle systems, having application to many-electron atoms, molecules, condensed matter and nuclei. Selection of topics varies and may include Hartree-Fock and Fermi-Thomas and their modern descendants: X-alpha, Green's Functions, Feynman graphs, density functionals; applications of group theory to symmetric clusters of atoms.

95-662 Nuclear Physics II (3-0)3
Prerequisite 95.561
The nucleon-nucleon force; nuclear models; nuclear reaction theory and partial wave analysis of scattering; fast neutron physics.

95-673/674 Advanced Theory of Solids I, II
(3-0)3
Prerequisite: 95-616 and Permission of Instructor
Lattice vibrations and their interactions with X-rays, neutrons and light. The band model of solids and energy band calculations; the Fermi surface. Transport and optical properties in metals and semiconductors. Magnetism and magnetic resonance; superconductivity. Many-body theory and applications; collective excitations; Green's function techniques in solid state physics.

95-675/676 Neutral Particle Transport I, II
(3-0) (3-0)6
Prerequisite: Permission of Instructor
Boltzmann and integral transport equations. Spherical harmonic and variational methods, special methods of solving transport equations. Corrections to diffusion theory. Adjoint functions. Applications.

95-683/684 General Theory of Relativity I, II
(3-0) (3-0)6
Prerequisite: Permission of Instructor
Review of Newtonian gravitational theory and special relativity. Principles of equivalence. Tensor analysis in Riemann spaces. Einstein's field equations; tests of Einstein's theory. Spherically symmetric solutions. Applications in astrophysics and cosmology.

95-701/702 Physics Colloquium (1-0) (1-0)2
A series of invited lectures on current research topics in Physics.

95-703/704 Seminar in Nuclear Physics (1-0) (1-0)2

95-705/706 Seminar in Solid State/Optics
(1-0) (1-0)2

95-707/708 Seminar in Theoretical Physics
(1-0) (1-0)2
The preceding three seminars involve presentations by students, faculty members, and visiting scientists of advanced topics, original research or journal articles.

95-711/712 Graduate Seminar in Physics
(1-0) (1-0)2
Presentations by students of progress in their research projects.

95-721/722 Selected Topics in Physics (3-0) (3-0)6

95-723/724 Selected Topics in Nuclear Physics (3-0) (3-0)6

95-725/726 Selected Topics in Solid State Physics (3-0) (3-0)6

95-727/728 Selected Topics in Theoretical Physics (3-0) (3-0)6
The preceding selected topics courses cover recent advances and more advanced topics, not covered in the regular courses in these areas. Subject matter varies, depending on the interests of the instructor and the needs of the students. Subject matter varies sufficiently that these courses may be taken more than once for credit without repeating topics.

96-539 Electro-optics Laboratory (0-3)2
Co-requisite: 95-439/539
Studies of monochromators, optical filters, photomultiplier tubes, evaporation of thin films and thickness measurements of thin films. The following projects are offered: dye laser, ring dye laser, nitrogen gas laser, semiconductor laser, argon ion laser, mercury ion laser, CO_2 laser, ellipsometric measurement on thermally evaporated thin films, absorption of surface plasma waves, vacuum engineering, E-O coefficients of Pockels cells, detectivity D* of infrared detectors, A-O Q-switching in YAG lasers, interferometers and interference filters.

96-593 Graduate Physics Laboratory (0-4)2
Experiments in various branches of physics including optics, atomic physics, solid state physics and nuclear physics.

96-713/716/719 Special Problems in Physics (0-9)3, (0-9)6, (0-27)9
Prerequisite: Written Permission of Supervisor
Reading in preparation for research, or research not for thesis. If results of the research are to be subsequently incorporated into a thesis, credits earned in this course may be used to satisfy thesis credit requirements in M.S. or Ph.D. Thesis Research with the written permission of the thesis super-visor, provided such permission is granted at the time of registration for this course. If the results are incorporated in an M.S. project, not more than 3 credits are allowed.

96-740 M.S. Research Project in Physics (0-9)3
Prerequisite: Departmental approval of an M.S. Project Proposal and written permission of supervisor.

96-743/746/749 M.S. Thesis Research in Physics (0-9)3, (0-18)6, (0-27)9
Prerequisite: Departmental approval of an M.S. Thesis proposal and written permission of supervisor.

96-751/752 Advanced Projects in Physics I, II (3-0) (3-0)6
Prerequisite: Written Permission of Supervisor
Research project leading to the Graduate Research Admission Examination (for Ph.D. candidates only).

96-753/756/759 Ph.D. Dissertation Research in Physics (0-9)3, 3(0-18)6, (0-27)9
Prerequisite: Departmental approval of a Ph.D. dissertation proposal and written permission of supervisor.

Radiological Sciences and Protection (Department of Physics)

Graduate Coordinator: Jesse Y. Harris, Professor; B.S., M.S., Ph.D., Rutgers-The State University.
Faculty: George E. Chabot, Assistant Professor; A.B., Harvard University; M.S., Harvard School of Public Health; Ph.D., University of Lowell; (C.H.P.); Clayton S. French, Assistant Professor; B.S., M.S., Ph.D., University of Lowell; (C.H.P.); Paul J. Ring, Associate Professor; B.S., Boston College; M.S., Rensselaer Polytechnic Institute; Ph.D., Brown University; Kenneth W. Skrable, Professor; B.S., Moravian College; M.S., Vanderbilt University; Ph.D., Rutgers-The State University; (C.H.P.).

Master of Science Degree Program

With the increasing uses of radiation and radioactive materials by industry and medicine and the continued use of nuclear power, there is a growing need for research in Radiological Sciences and Protection. The excellent facilities, equipment and supporting staff available at the University's Radiation Laboratory and the well-qualified faculty in the Radiological Sciences program and in other allied departments give students at the University of Lowell a unique opportunity to make significant contributions to research in the radiation protection field.

The Master of Science degree program in Radiological Sciences and Protection is interdisciplinary in nature and is appropriate for students with backgrounds in engineering and the biological and physical sciences. The program is complementary to the Master of Science degree programs in Environmental Studies and Work Environment, enabling students at the University to pursue careers in all the major areas of environmental protection. Cooperative programs with medical facilities enable students to pursue professional education and training in medical health physics and medical radiation physics.

The high level of concern exhibited today regarding the environment and the safety of nuclear facilities has created a critical shortage of professionals needed to perform evaluations of the environmental impact of nuclear reactors, waste processing plants, and other nuclear facilities. Students in the program are given the opportunity to select a program from the varied resources of the University that will prepare them for one of the many positions available.

Admission Requirements

A student should have preparation in mathematics, including differential and integral calculus through differential equations, chemistry, physics, biology and in nuclear and radiological sciences similar to the University of Lowell Radiological Health Physics undergraduate curriculum. The applicant must submit the applications materials provided by the Graduate School, official transcripts of all undergraduate work, and the official score report for the Graduate Record Examination Aptitude Test.

Plan of Study

The program allows a student to select courses and a research project consistent with his/her desired area of professional development. Various opportunities for research and professional development are possible through the use of the Radiation Laboratory of the University and through cooperative programs with hospitals, nuclear reactor facilities, government laboratories, and other radiation facilities. A research adviser, other than a University of Lowell faculty member, may be approved for the conduct of research at facilities outside the University. A student's program must receive departmental approval. Three Master of Science degree options are available: (1) thesis, (2) project, or (3) critical essay. In addition to a core curriculum, a master's thesis, project report, or critical essay thus must be submitted and approved.

Thesis Option

Under the thesis option, a student must complete a minimum of 21 credits of formal courses and a minimum of 9 credits of graduate research. The master's thesis generally will consist of a scholarly laboratory or theoretical investigation in the field of Radiological Sciences and Protection. Proposed research must be approved by the Program Graduate Committee. The format for the final written thesis shall conform to the requirements of the Graduate School. The thesis proposal and report requirements may be obtained from the Graduate Coordinator.

Oral Defense of Thesis

A thesis committee is appointed to read a student's thesis and to listen to an oral presentation and defense presented by the student. In general, the committee will include the thesis adviser and two additional members chosen from the Radiological Sciences faculty and other departments in which the candidate has taken graduate studies.

Project Option

Under the project option, a student must complete a minimum of 24 credits of formal courses and a minimum of 3 and a maximum

of 6 credits of graduate research to yield a total of 30 credits. In addition to the project report, the student must pass a comprehensive examination. The master's project consists of a scholarly investigation such as a review, report, design, etc., in the field of Radiological Sciences and Protection. The subject of the project must be approved by the student's adviser in advance. The final report must be approved by the Program Graduate Committee and conform to the format specified by the Graduate School.

Critical Essay Option

Under the critical essay option, a student must complete a minimum of 27 credits of formal courses and a 3 credit critical essay. The critical essay consists of a scholarly investigation including a detailed literature search but not involving any laboratory investigation. The subject of the critical essay must be approved by the student's advisor in advance. The final critical essay must be approved by the Program Graduate Committee and conform to the format specified by the Graduate School.

Comprehensive Examination for Non-Thesis Options

Degree candidates electing the project or critical essay option are required to pass a comprehensive written and/or oral examination administered by the Program Graduate Committee. This examination normally will be administered during the semester in which the student completes his or her course requirements for the master's degree. The comprehensive examination may be waived for a student who can document that he/she has passed Part I of the American Board of Health Physics Certification Examination.

Core Curriculum

A core curriculum consisting of nine courses is required of all students. These core courses are listed below along with other courses offered by the Department for graduate credit. If a student has already had a course or courses similar to those listed, then the requirement for such courses may be waived. Courses in Nuclear Engineering, Physics and Applied Physics, Environmental Studies,Work Environment, Biology, Mathematics, Meteorology, Chemistry, and others may be selected for graduate credit with the approval of the Department.

Required Core Courses

24-533	Nuclear Instrumentation I	3
80-505	Nuclear Instrumentation II	4
98-501	Radiation Safety or Control I	4
98-502	Radiation Safety or Control II	4
98-555	Physics of Radiation and Nuclei I	3
98-556	Physics of Radiation and Nuclei II	3
98-572	Radiation Biology	3
98-605	Radiation Dosimetry	3
98-632	Intro to Nuclear Radiation Shielding	3
98-711/712	Grad Seminar in Rad Sci Prot	2
98-730	Critical Essay in Radiological Sci & Prot	3
	or	
98-733/736	M.S. Proj in Rad Sci & Prot(Project Option)	3, 6
	or	
98-743/746/749	M.S. Res in RSP (Thesis Option)	3, 6, 9

Five Year B.S./M.S. Degree Program

A five-year B.S./M.S. program is available to well qualified undergraduates. For information, see the description at the front of this catalog.

Graduate Radiological Science & Protection Internships

It is highly desirable that every graduate of the Radiological Science and Protection program have work experience in the field of specialization. Students may receive academic credit for volunteer or paid work experience that meets the guidelines established by the program graduate committee. Students are permitted to register for only one internship course during a semester. A minimum of 135 hours of applicable and satisfactory work experience is required during the semester to receive a passing grade. No credit is allowed for work experience gained prior to registering for the course. A maximum of 3 credits of internship courses may be applied toward the minimum of 30 credits required for the M.S. degree, and a maximum of 6 credits may be applied toward the Ph.D. requirements. Only matriculated students may register for internship courses, and the student is allowed to register for a total of no more than two internship courses.

Doctor of Philosophy Degree Program

See Physics and Applied Physics section in this catalog.

Courses of Study

98-501 Principles of Radiation Safety and Control (3-0)4
Prerequisite: 80-202 or equivalent
Introduction to radiation protection, including radiation sources, radiation dose and dose measurement, radiation monitoring methods and instruments, contamination control and applied health physics techniques for the safe handling and control of radioactive material.

98-502 Principles of Radiation Safety and Control (3-3)4
Prerequisite: 98-501
A laboratory course giving students experience with equipment and practices of current use in the radiation protection field; an extension of 98-501 giving some of the practical aspects of radiation safety and control.

98-522 Environmental Radiation and Nuclear Site Criteria (3-0)3
Prerequisite: Introductory Course Covering Basic Nuclear Concepts
Study of sources, distribution, environmental transport and dose projections of environmental radionuclides. Emphasis on environmental impact of nuclear fuel cycle.

98-541 Radiosotope Techniques (3-0)3
Prerequisite: Undergraduate background in sciences or engineering
Study of the theory and use of radionuclides as tracers and the principles of operation of radiation counting systems.

98-543 Radioisotope Techniques Laboratory (0-3)1
Prerequisite: 98-541 concurrently
Laboratory experience in tracer techniques including use of GM, proportional, and various scintillation systems for counting alpha, beta, and gamma radiations. Applications in chemistry and biology.

98-555 Physics of Radiation & Nuclei I (3-0)3
Prerequisite: 95-144 or equivalent.
A survey of atomic and nuclear physics directed to an understanding of the basic modern physics utilized in radiological science and nuclear engineering. Material covered includes but is not limited to the following topics: Classical and relativistic relationships for momentum and energy, mass energy relationships, motion of charged particles in charged and magnetic fields, mass and charge of electron, atomic mass and isotopes, the photon, photoelectric effect, the Compton effect, wave particle dualism and probability, absorption of photons, scattering and cross sections, Rutherford's nuclear atom, atomic spectra and Bohr's theory of the hydrogen atom, emission and absorption spectra and selection rules, DeBroglie hypothesis, neutron diffraction, the Schroedinger wave equation, the uncertainty principle, systematics and structure of the nucleus, nuclear forces and nuclear models.

98-556 Physics of Radiation & Nuclei II (3-0)3
Prerequisite: 98-555
Subject matter will be selected on the basis of its fundamental usefulness in radiological health physics. Material covered in Physics of Radiation and Nuclei I will be re-examined and studied in greater depth. Other topics such as neutron physics, nuclear fission and fusion, nuclear models and forces, accelerator physics, lasers, theory of solids, solid state devices and detectors, and energy deposition by particulate and electromagnetic radiation will be covered when time and interest permit.

98-561/562 Special Topics in Radiological Sciences (3-0)3
This course is used to provide students with current information on topics of interest to graduate students in Radiological Sciences and Protec-

tion. Topics covered may vary from year to year. Topics are announced prior to registration.

98-572 Radiation Biology (3-0)3
Prerequisite: Introductory nuclear course and course in human physiology
Study of biological effects and mechanisms of action of ionizing radiations from subcellular through whole organism and ecological levels.

98-581 Math Methods in RS&P (3-0)3
Prerequisite: Permission of instructor.
A course for those majoring in Radiological Sciences and Protection. An applied course emphasizing the mathematical skills used in radiological sciences/health physics fields including special techniques used in radiation physics, radiation dosimetry, and radiation shielding. Microcomputer applications including numerical techniques will be included.

98-582 Numerical Methods in RS&P (3-0)3
Prerequisite: 98:581 and permission of instructor.
Advanced mathematical treatment of topics covered in 98:581 with extensive application of computer techniques to problem solutions applicable to Radiological Sciences and Protection.

98-601 Radiochemistry (3-0)3
Prerequisite: Permission of instructor.
This course stresses analytical techniques applicable to identification and quantification of radionuclides in various sample types. Considerable time will be spent on review of general chemistry and inorganic analytical chemistry. The theories and applications of various separation techniques including precipitation, solvent extraction, ion exchange chromatography, and electrodeposition will be discussed with emphasis on separation of radioactive species. Additional material to be covered includes instrumental techniques for analysis of radioactive species, radiotracer and isotope dilution techniques, saturation activation analysis, and sample preparation.

98-603 Radiochemistry Laboratory (0-3)1
Corequisite: 98-601
This laboratory course will require the completion of between 4 and 6 separate laboratory procedures and participation in 2 to 4 demonstration sessions. Laboratories will stress various analytical techniques for determination of specific radionuclides. At least two laboratory sessions, which may extend more than one period, will deal with analysis of environmental samples of specific radionuclides. A variety of separation procedures including precipitation, solvent extraction, ion exchange chromatography, gas deemanation, and electro-deposition will be employed.

98-605 Radiation Dosimetry (3-0)3
Prerequisite: 98-501/502
Sources of radiation exposure; calculations of chronic and acute radiation doses and their effects; internal dosimetry including distribution and elimination of radionuclides; internal beta, gamma, and neutron dosimetry; use and calibration of instruments in dose related measurements.

98-607 Radiation Dosimetry laboratory (not offered every year) (0-3)1
Prerequisite: 98-505 concurrently
Laboratory experience coordinated with lecture sequence in 98-505.

98-608 Environmental Toxicology and Epidemiology (3-0)3
Prerequisite: Graduate student with science background
Study of toxicology and epidemiology of physical and chemical agents including: air pollutants, food additives, ionizing and non-ionizing radiations, review of current health standards.

98-610 Environmental Toxicology Laboratory (0-3)1
Prerequisite: 98-508 concurrently
Laboratory studies of effects of toxic agents on plant and animal systems with emphasis on radiation and air pollutants.

98-611 Preparation for Health Physics Certificate (3-03)
Prerequsite: Qualified to take part I of certification examination of ABHP
Students have intensive review of problems from historical certification examinations and review of current federal regulations related to applied health physics.

98-613 Environmental Monitoring and Surveillance (3-0)3
Prerequisite: 98-502
Sources of environmental radioactivity; design of monitoring programs; sampling and analytical measurement programs for specific radionuclides and external radiation sources; analytical equipment and procedures; design of an environmental laboratory; and quality assurance programs.

98-614 External Radiation Dosimetry (3-3)4
Prerequisite: 98-501/502
Radiation quantities and units; beta, gamma and neutron dosimetry; principles of charge measurement and energy transfer; use and calibration of instruments; calibration sources; accident dosimetry; standards and regulations.

98-615 Internal Radiation Dosimetry (3-0)3
Prerequisite: Permission of Instructor
Physiological models for reference man; metabolic models and kinetics; 1959 ICRP 2 and the 1978 ICRP 30 publications; bioassay models; accident internal radiation dosimetry; standards and regulatory requirements.

98-616 Data Reduction for Radiological Sciences and Protection (3-0)3
Prerequisite: Permission of Instructor
Fundamental statistical concepts; sampling and counting experiments; propagation of errors; minimum detectable activity and lower limit of detection; chi square and other statistical tests; tests of distributions and fitting functions.

98-620 Environmental Impact Statements (3-0)3
Methodology for preparation of environmental impact statements. Review National Environmental Policy Act and applications to federal and state projects. Review of current administrative procedures for nuclear and non-nuclear projects. Students prepare an EIS for a local project of current interest.

98-625 Medical Health Physics (3-0)3
Prerequisite: 98-501 and 81-252 or equivalent
Medical applications of radiation and radioactive material in diagnosis and radiation therapy; shielding of X-ray and radiation therapy facilities; survey and monitoring instruments and procedures; regulations; waste disposal; and clinical support role of health physicist.

98-632 Introduction to Nuclear Radiation Shielding (3-0)3
Prerequisite: Permission of Instructor, Advanced Calculus
Interaction of neutrons, gamma rays and charged particles with matter; buildup factors; shielding of point, surface, and volume sources; shielding design factors in reactor and accelerator operations.

98-634 Introduction to Radiation Shielding Laboratory (not offered every year) (0-3)1
Prerequisite: 98-532 concurrently
Laboratory coordinated with 98-532 with applications to health physics problems.

98-646 Accelerator Health Physics (3-0)3
Prerequisite: 98-501/502
Health physics problems common to particle accelerator facilities are presented with discussions of current approaches to their solutions. Estimation of the levels of induced radioactivity expected and calculations of shielding and ventilation requirements will be made for a variety of particle accelerators.

98-651 Introduction to Electronic Product Radiation (3-0)3
Prerequisite: 98-501
The generation, measurement, and uses of radiant energy from electronic products whose emissions span the entire electromagnetic spectrum; ultrasonic energy emitted by electronic products, biological effects, standards of protection and control, and consequences and intent of Public Law 90-602.

98-663 Introduction to Radiation Chemistry (not offered every year) (3-0)3
Prerequisite: Permission of Instructor
A study of the interaction of all types of ionizing radiation with matter and the resulting radiation-induced chemical reactions; excitation, ionization, and free radical formation and recombination.

98-666 Reactor Health Physics
Prerequisite: 98-501/502
Health physics problems associated with nuclear reactor facilities with emphasis on commercial nuclear power including the radiation protection program elements needed for the control of external and internal radiation sources for the safe and efficient operations of these facilities.

98-668 Applied Health Physics (2-3)3
Prerequsite:98-502
This course deals with selected topics of concern to the practicing health physicist and stresses application of principles and techniques not covered in depth in other courses. Topics include air sampling and analysis, meteorology, monitoring instrumentation, ventilation control and assessment, respiratory protection, and contamination control. Laboratory sessions will reinforce practical considerations and problems encountered in the field.

98-681 Medical Physics (3-0)3
Prerequisite: Permission of Instructor
A discussion of the methods and procedures involving the use of radiation and radioactive materials in medical diagnosis and therapy, including medical radiation dosimetry and computer applications.

98-682 Medical Physics Laboratory (0-9)3
Prerequisite: 98-681
A clincial laboratory course involving practical applications and experience in the subject matter covered in 98-581 through cooperative programs with participating medical facilities.

98-683 Grad Health Physics Internship (0-9)3
Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98-684 Grad Accelerator Health Physics Internship (0-9)3
Prerequsite: Requires advance approval of site supervisor and RS graduate coordinator.

98-685 Grad Reactor Health Physics Internship (0-9)3
Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98-686 Grad Medical Health Physics Internship (0-9)3
Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98-687 Grad Medical Physics Internship (0-9)3
Prerequisite: Requires advance approval of site supervisor and RS graduate coordinator.

98-693 Adv Grad Health Physics Internship (0-9)3
Prerequisite: 98-683 and advance approval.

98-694 Adv Grad Accelerator Health Physics Internship (0-9)3
Prerequisite: 98-684 and advance approval.

98-695 Adv Grad Reactor Health Physics Internship (0-9)3
Prerequisite: 98-685 and advance approval

98-696 Adv Grad Medical Health Physics Internship (0-9)3
Prerequisite: 98-686 and advance approval.

98-697 Adv Grad Medical Physics Internship (0-9)3
Prerequisite: 98-687 and advance approval.

98-711/712 Grad Seminar in Rad Sci & Prot (1-0)1
Individual presentations by students and staff of advanced topics, original research or journal articles.

98-730 MS Critical Essay in Rad Sci & Prot (0-9)3
Prerequisite: Election of critical essay MS option and permission of faculty advisor.

98-733/736 MS Project in Rad Sci & Prot (0-9)3, (0-18)6
Prerequisite: Selection of project option, completion of a minimum of one semester of graduate study in Radiological Sciences and Protection and approval of proposal by faculty advisor.
This course provides research credit for a project done by master's degree candidates.

98-743/746/749 M.S. Thesis Research in RSP (0-9)3, (0-18)6, (0-27)9
Prerequisite: Completion of a minimum of one semester of graduate study in Radiological Sciences and Protection and approval of proposal by thesis committee.
This course provides credit for thesis research done by master's degree candidates.

98-751/752 Advanced Projects in RSP (0-3)1, (0-9)3
An opportunity for individual study under the direction of a staff member of topics related to Radiological Sciences and Protection.

Graduate Courses for Non-Majors (not to satisfy major requirements)

99-522 Environmental Radiation and Health (3-0)3
A course to introduce the non-major to the sources of man-made and natural radiation, radioactive decay, mechanisms of radiation interaction with matter, biological effects. and standards relating to concentration limits in air, water, and other environmental media. The comparative environmental impact of nuclear and fossil fueled power plants will be discussed. May not be credited to RSP major.

99-527 Radon in the Environment (3-0)3
A course to introduce the non-major to the sources and variability of radon in the environment and associated health risks as well as general measurement techniques and mitigation procedures. May not be credited to RSP major.

99-561/562 Special Topics in Rad Sci & Prot (3-0)3, (3-0)3
This course is used to provide non-major students with current information on a variety of topics in Radiological Sciences. Topics covered are announced prior to registration. May not be credited to Radiological Sciences and Protection major.

College of Education

Dean: Donald E. Pierson, Professor; A.B., Princeton University; Ed.M., Ph.D., Harvard University.

Assistant Dean: Gail M. Carney, Assistant Professor; B.A., Framingham State College; Ed. M., University of Lowell; Ed.D., Boston University.

Chairperson of the Faculty: Norman F. Benson, Professor; B.S., A.M., University of Minnesota; Ed.D., Ball State University.

Resident Faculty: Richard Ackerman, Assistant Professor; B.A., University of Wisconsin; B.S., Bank Street College of Education; Ed.M., Ed.D., Harvard University; Judith A. Boccia, Assistant Professor and Acting Director, Center for Field Services & Studies; B.A., Marymount College; M.A., University of North Carolina at Chapel Hill; Ed.D., Teachers College, Columbia University; Vivian M. Camerlengo, Associate Professor; B.A., Regis College; Ed.M., St. Michael's College; Ph. D., University of Florida; James M. Carifio, Assistant Professor; B.A., Columbia College, Columbia University; Ed.M., Ed.D., Boston University; John J. Catallozzi, Associate Professor; B.S., University of Lowell; Ed.M., Ed.D., Boston University; Lorraine Dagostino, Assistant Professor; B.A., Russell Sage College; M.A., College of St. Rose; Ph.D., Syracuse University; Thomas G. Devine, Professor; B.A., M.A., Ed.D., Boston University; Robert R. Gower, Associate Professor; B.S., State College at Bloomsburg, PA; M.A., Ed.D., Teachers College, Columbia University; David L. Haury, Associate Professor; B.A., M.A., University of Oregon; Ph.D., University of Washington; Brenda L. Jochums, Associate Professor; B.S., University of Illinois; M.A., Bradley University; Ph.D., Indiana University; John F. LeBaron, Associate Professor; B.A., McGill University; Ed.M., Ed.D., University of Massachusetts at Amherst; Richard G. Lyons, Professor; B.S., Ed.M., Ph.D., Boston University; Anne M. McParland, Associate Professor; B.S., University of Lowell; C.A.S., Harvard University; Ed.M., Ed.D., Boston University; Dorothy V. Meyer, Associate Professor; A.B., Houghton College; Ed.M., Ed.D., Boston University; Susan B. Neuman, Associate Professor; B.A., American University; M.A., California State University at Hayward; Ed.D., University of the Pacific; Edward J. Pershey, Adjunct Professor and Director, Tsongas Center for Industrial History; B.A., Ph.D., Case Western Reserve University; William T. Phelan, Associate Professor; A.B., Boston College; A.M., Catholic University; Ph.D., University of Chicago; Juan C. Rodriguez, Assistant Professor and Coordinator of Bilingual and ESL Programs; B.A., Ed.M., Catholic University, Lima, Peru; Ed.D., University of Massachusetts at Amherst; Paula I. Robbins, Assistant Professor and Assistant Dean of the Graduate School; B.A., Vassar College; M.Ed., Boston University; Ph.D., University of Connecticut; Nancy B. Wyner, Associate Professor; B.A., Boston University; M.A., Ed.D., Teachers College, Columbia University; J.D., Northeastern University Law School; Dana L. Zeidler, Associate Professor; B.S., State University of New York; M.S., Ph.D., Syracuse University.

Emeriti: M. Virginia Biggy, Dean Emerita and Professor; B.S., Ed.M., Ed.D., Boston University; Penelope A. Demogenes, Associate Professor Emerita; B.S., University of Lowell; Ed.M., C.A.G.S., Boston University; Alice C. Kiernan, Associate Professor Emerita; B.S., University of Lowell; Ed.M., Boston University; Mary E. McGauvran, Professor Emerita; B.S.Ed., University of Lowell; Ed.M., Ed.D., Boston University; Margaret R. Shannon, Dean Emerita and Professor; B.S., University of Lowell; Ed.M., Ed.D., Harvard University.

The College of Education offers graduate degree programs which provide professional preparation for those who aspire to serve in the role of teacher, educational specialist, educational or human service administrator, media and educational technology specialist, higher education faculty, and other positions of leadership.

The Master of Education degree is offered in: Curriculum and Instruction with options in Initial Teacher Certification, English as a Second Language, Bilingual Education, Technology & Learning Environments, Administration, Planning, and Policy (with an option in Human Services non-Health Services), and Reading and Language.

The Certificate of Advanced Graduate Study is offered in: Reading and Language, Administration, Planning and Policy, and Curriculum and Instruction with an option in Technology and Learning Environments.

The Doctor of Education Degree offers specialization in: Leadership in Schooling, Language Arts and Literacy, and Mathematics and Science Education.

Admission to Degree Programs in Education

Admissions: The Academic Standards and Admissions Committee of the College of Education determines acceptance. This committee meets once a month and is comprised of faculty representatives from each strand of the doctoral program. Application Procedure: Each applicant must file the following documents with the Graduate School:

1. A completed application form obtained from the Graduate School Office.
2. One copy of the applicant's teaching certificate must be mailed with the completed application form, if applicable.
3. Two official transcripts from each undergraduate college and graduate school which the applicant attended. These official transcripts must be sent to the Graduate School by the colleges which the applicant attended. Transcripts or copies thereof sent by the applicant are not official and will not be accepted.
4. An official copy of the applicant's scores obtained on the Miller Analogies Test or Graduate Record Examination must be mailed directly to the Graduate School Office by the institution which administered the test.
5. Letters of recommendation from three persons who are qualified to evaluate the applicant's academic and professional abilities. The forms for such recommendations are contained in the admission packet.

Upon receipt of all of the above documents, the Graduate School will forward them to the College of Education. All decisions on admissions are made by the Academic Standards and Admissions Committee of the College of Education and forwarded to the Graduate School for final action.

Transfer Credit: M. Ed., C.A.G.S., and Ed. D. Programs
The College of Education follows the Graduate School requirements regarding transfer of credit (see front of catalog) with the following exceptions. No more than twelve (12) credits (Master's) or nine (9) credits (C.A.G.S.) or twenty-four (24) credits (Ed.D.) of earned graduate credit with grade of B or better may be transferred from other accredited institutions of higher education.

Graduate Advisor: A student who accepts admission will be assigned to a faculty advisor in the College of Education. The advisor's responsibility is to: 1) provide academic counseling to the student relative to his/her program; 2) approve the program of studies which the student shall present, and also approve all changes in that program; and 3) periodically evaluate the student's academic progress and make recommendations to the Graduate Admissions Committee concerning the student's continuance, dismissal, or recommendation for a degree.

Degree Requirements

Each graduate student is personally responsible for complying with all the rules and regulations of the Graduate School and the College of Education, and fulfilling all degree requirements.

Master of Education (M.Ed.)

To qualify for admission to a graduate degree program at the Master of Education level, an applicant must have completed his or her baccalaureate degree program with a scholastic record that gives evidence of ability to do graduate work with a cumulative average of no less than 2.75 (on a 4.0 scale);

In order to qualify for a Master of Education degree, each candidate must meet the following requirements:

1. Complete a minimum of thirty (30) credits of required course work in a specific degree program. Most degree programs have a higher minimum semester hour credit requirement.
2. Complete all course requirements for the degree program at this University. A maximum of twelve (12) credits of course work taken at another accredited institution is the only exception given.
3. Complete satisfactorily the specified internship and/or field practicum, and appropriate seminar, under the supervision of a designated faculty member in the College of Education. This requirement may not be waived.
4. Complete all course requirements for the degree with a cumulative grade-point average of B or better. No additional course credits may be permitted in order to achieve the grade-point average of B or better required for the degree.
5. Complete the degree within five years of the date of admission.

A. Curriculum and Instruction(M.Ed.)

The program in Curriculum and Instruction is designed for pre-service teachers in elementary and secondary schools and for experienced teachers who will provide instructional leadership in the role of supervisor, department chairperson, or curriculum specialist. In conjunction with this program, certification opportunities are available in the following areas: Elementary Education, Secondary Education, Art Education (5-12), Bilingual Education, English as a Second Language, and Supervisor/Director. Program options include: Initial Teacher Certification, Bilingual Education, English as a Second Language, and Technology and Learning Environments. The core of the Master of Education degree consists of distribution requirements in the following areas: Foundations of Education, Research and Evaluation, Specialization, Practicum, and Electives. Course offerings which apply to each area are listed below.

1. Initial Teacher Certification:

Foundations of Education (minimum 6 credits)

02.559 Developmental Psychology
02.565 Issues of Educating Minority Students in Schools
02.564 History of American Education (Art and Secondary)

Research and Evaluation (minimum 3 credits)

02.558 Measurement and Evaluation

Elementary Education Specialization (minimum 23 credits)

02.550 Reading Education
02.551 Mathematics Education
02.552 Social Studies and Science Education
02.553 Language Arts Education
02.554 Analysis of Teaching
02.555 Literature for Children
02.556 Reading Disabilities
02.579 Seminar in Elementary Education

Secondary Education Specialization (minimum 15 credits)

02.560 Curriculum Development: Middle/Secondary
02.XXX Curriculum and Teaching in Major Area
02.557 Reading Education: Middle/Secondary
02.596 Seminar in Middle/Secondary Education

Art Education (5-12) Specialization (minimum 9 credits)

02.561 Integration of Art in the Curriculum
02.570 Curriculum and Teaching Art (5-12)
02.595 Seminar in Art Education

Practicum (Minimum 12 credits)

02.578 Teaching: Elementary
02.XXX Teaching: Major Area Secondary Level
02.581 Teaching: Art (5-12)

Prerequisite: Completion of the Elementary, Secondary, or Art Education Field of Knowledge requirements.

2. Bilingual Education

Foundations of Education (minimum 15 credits)

02.500 Contemporary American Culture: Pluralism and Native Identity
02.502 Contemporary Issues and Mandates in the Education of Language Minority Children
01.635 Culture of the School
02.516 Culture of the Caribbean and Southeast Asia
02.518 Community Organization and Parental Participation

Research and Evaluation (minimum 3 credits)

02.524 Assessment/Diagnosis of Abilities and Achievement of Bilingual Students

Specialization (Minimum 15 credits)

02.518 Resources and Techniques in Bilingual Education
02.520 Teaching Reading to Bilingual Students
02.521 Design/Adaption of Curriculum and Instruction (Materials for Bilingual Education Program)
02.519 Methods of Teaching Content Area/Language Acquisition
02.509 The Bilingual Child With Special Needs

Practicum (minimum 3 credits)

02.525 Field Work/Internship

Electives (minimum 3 credits)

02.508 Approaches to Second Language Testing and Assessment
02.520 Teaching Reading in English to Bilingual Students

Language Proficiency Examination is required by the State Department of Education to be a certified Bilingual teacher.

3. English As A Second Language

Foundations of Education (minimum 15 credits)

02.500 Contemporary American Culture: Pluralism and Native Identity
02.502 Contemporary Issues and Mandates in the Education of Language Minority Children
01.635 Culture of the School
02.517 Culture of the Caribbean and Southeast Asia
02.518 Community Organization and Parental Participation

Research and Evaluation (minimum 3 credits.)

02.508 Approaches to Second Language Testing and Assessment

Specialization (minimum 15 credits)

02.501 Introduction to Second Language Acquisition
02.503 Methods of Second Language Instruction
02.504 Curriculum Material and Adaption in ESL
02.505 Language Art Instruction
02.509 The Bilingual Child with Special Needs

Practicum (Minimum 3 credits)

02.515 Field Work/Internship

Electives (Minimum of 3 credits)

02.522 Teaching Conversational Skills in English
02.507 Dialogue Writing: Student/Teacher Interactions

Prerequisite: A minimum of 6 credits in American Literature and 6 credits in English Literature is required. The Language Proficiency Examination is required by the State Department of Education to be a certified ESL teacher.

4. Curriculum and Instruction Field

Foundations of Education (minimum 6 credits)

Two 01 courses with the advice and approval of the Faculty advisor.

Research and Evaluation (minimum 3 credits)

07.640 Research Methods

Specialization (minimum 12 credits)

04.636 Theory and Research in Curriculum
04.639 Planning Process
04.638 Curriculum Design: K-12
04.656 Seminar in Curriculum and Instruction

Practicum (minimum 3 credits)

04.649 Practicum Internship: Supervisor/Director
04.650 Practicum in Curriculum and Instruction [non-certification]

Electives Three or four courses must be selected from courses numbered 03, 04, 05, or 06, with the advice and approval of the student's faculty advisor.

Students seeking certification as Supervisor/Director must be certain that all courses required for certification are completed.

Option:

Technology & Learning Environments Specialization (minimum 12 credits)

04.636 Theory and Research in Curriculum
04.639 Planning Process
03.651 Technology and Learning Environments
03.661 Curriculum Development for Technology-Based Instruction

Electives Minimum (9 credits) Three or four electives, two of which must be selected from courses numbered 03 with the advice and approval of the faculty advisor.

B. Administration, Planning and Policy Program.(M.Ed.)

The master's degree program in Administration, Planning and Policy is designed to meet the needs of those planning careers as practitioners in a variety of middle-level administrative areas in public and private educational institutions as well as community organizations and various human service agencies. The program also serves as the initial sequence of study for those planning further graduate study in administration in preparation for careers as top-level administrators, planners, researchers, or theorists.

Students have the option of pursuing one of two means of completing degree requirements:

1. Complete 36 credits including all required courses.
2. Complete 30 credits including all required courses and complete a project or paper of substantial depth which would demonstrate the student's expertise. A student undertaking a project or specialized paper must make a decision to do so early in the program so that the student might work with a faculty mentor from the initial plan to completion. Projects and/or papers must be accepted by a faculty committee. Students considering advanced study in this area should consider option #2.

Foundations of Education (minimum 6 credits)

Two courses are required in this area and may be selected from courses beginning with the 01 prefix.

Research and Evaluation (minimum 3 credits)

One course in research methodology is required.

Specialization in Administration, Planning and Policy (minimum 12 credits)

05.620 Introduction to Educational and Human Service Adm.
05.639 Planning Process or 04.639
05.640 Analysis of Educational and Human Service Organizations
05.643 Principalship or
05.642 Principles of Supervision
05.644 Practicum in Educational Administration (non-certification)

Electives (minimum 12 credits)

(To be selected: 05 electives are possible with the advice and approval of the advisor.)

Practicum (minimum 3 credits)

05.646 School Principal N-6
05.647 School Principal 5-9
05.648 School Principal 9-12
05.645 Human Services

Professional Experience: Each candidate for the degree in Administration, Planning and Policy is required to completed at least three years of full time employment in an educational institution or a human service agency prior to completion of degree requirements.

Students seeking certification as Principal must be certain that all courses required for certification are completed.

Please Note: Not all courses are offered every year; several are offered in alternate years only.

C. Reading and Language Degree Program (M.Ed.)

The Reading and Language Degree Program requires no less than 36 credits of course work including 9 credits in Practicum. Prerequisite Course Requirements: Two prerequisites for admission to the course entitled "Clinical Assessment of Reading and Language" are satisfactory completion of prior courses both in the teaching of reading in the elementary school and in the teaching of reading in the secondary school. These prerequisites may be met by satisfactory completion of the graduate courses entitled *"Developmental Reading: Secondary School"* and *"Developmental Reading: Elementary School."*

Foundations of Education (minimum 3 credits)

01.610 Theories of Learning

Research and Evaluation (minimum 3 credits)

07.640 Research Methods

Specialization in Reading and Language (minimum 18 credits)

06.627 Acquisition of Language
06.628 Clinical Assessment of Reading and Language Disabilities
06.629 Educational Treatment of Reading and Language Disabilities
06.630 Reading, Thinking, and Listening
06.631 Organization and Supervision of Reading and Language Program
06.649 Seminar: Reading and Language

Practicum (minimum 9 credits)

06.648 Practicum: Reading and Language Disabilities

901,902,903 *Electives (minimum 3 credits)*

One (1) or two (2) courses must be selected from courses numbered 01, 03, 04, or 06 with the advice and approval of the student's advisor.

Students seeking certification as Consulting Teacher of Reading must be certain that all courses for certification are completed.

Certificate of Advanced Graduate Study (C.A.G.S.)

To qualify for admission to a graduate program at the Certificate of Advanced Graduate Study level, an applicant must have a master's degree from an accredited college or university with a cumulative grade point average of no less than 3.0.

In order to qualify for a Certificate of Advanced Graduate Study, each candidate must meet the following requirements:

1. Complete a minimum of thirty (30) semester hours of required course work in the specified certificate program.
2. Complete all course requirements for the certificate program at this University. A maximum of nine (9) semester hours of course work taken at another accredited institution is the only exception granted.
3. Complete all course requirements for the certificate with a cumulative grade-point average of B or better. No additional course credits may be permitted in order to achieve the grade-point average of B or better required for the certificate.
4. Pass an area comprehensive examination.
5. Satisfactorily complete a Qualifying Paper as approved by his/her area faculty committee.
6. Complete the program within five years of the date of admission.
7. It is expected that an approved outline for a Qualifying Paper will be completed during the Research Seminar and the completed paper submitted no later than the 30th of April of the year that the student anticipates a June graduation.
8. Students must demonstrate competency in knowledge of research methods and computer literacy. This may be achieved by courses listed on transcripts, examinations or by other means approved by the student's advisor. Those students unable to fulfill this area by the stated means should take a course or courses to develop these competencies. Courses taken will not accrue to C.A.G.S. credit.

Note: Students seeking Massachusetts certification as Supervisor/Director, Principal, or Consulting Teacher of Reading must also fulfill a special set of courses and practica. Students should consult with the Assistant Dean before beginning course work.

A. Curriculum and Instruction Field (C.A.G.S.)

Core Requirements (minimum 9 credits)

04.670 Issues in Curriculum and Instruction
04.671 Research Seminar in Curriculum and Instruction
04.672 Research Seminar in Curriculum and Instruction

Specialization (minimum 12 credits)

04.638 Curriculum Design K-12
04.636 Theory and Research in Curriculum
04.639 Planning Process

04.642 Politics of Curriculum Change

Electives (minimum 9 credits)

Three (3) courses (9 credits) selected with advice and approval of the advisor from 01, 03, 04 courses

Those who have completed the C.A.G.S. specialization courses as part of their master's degree programs may meet the C.A.G.S. credit requirements by selecting other courses with the advice and approval of their advisor.

Students must take and pass the C.A.G.S. Comprehensive Examination in Curriculum and Instruction.

B. Curriculum and Instruction with an option in Technology and Learning Environments (C.A.G.S.)

Specialization (12 credits)

03.651 Technology and Learning Environments or
03.691 Policy Issues Related to Technology
03.690 Evaluation of Technological Curriculum or
03.680 Survey of Research on the Educational Impact of Technology-Based System or
04.623 Science, Technology and Society
04.639 Planning Process or
04.642 Politics of Curriculum Change
03.661 Curriculum Development for Technology-Based Systems

Electives (9 credits)

Three courses selected with advice and approval of the advisor from 01, 03, 04, or from other areas.

Students must take and pass a Comprehensive Examination in the area of Technology and Learning Environments.

C. Administration, Planning and Policy (C.A.G.S.)

Core Requirements (6 Credits)

05.670 Research Seminar in Administration, Planning and Policy
05.671 Research Seminar in Administration, Planning and Policy

Specialization (12 credits)

05.620 Introduction to Educational and Human Services Administration
05.640 Analysis of Educational and Human Service Organizations
05.639 Planning Process
05.643 Principalship or
05.642 Principles of Supervision

Electives (12 credits)

These courses may be selected with advice and approval of the advisor from 05 course offerings or other areas.

Students must take and pass a Comprehensive Examination in the content area of Administration, Planning and Policy.

D. Reading and Language (C.A.G.S.)

Core Requirements (minimum 9 credits)

06.670 Issues in Reading and Language Instruction
06.671 Research Seminar in Reading and Language
06.672 Research Seminar in Reading and Language

Specialization in Reading and Language (12 credits)

In consultation with the advisor, the student will select 12 credits of course work at the 06.650 or higher level.

Electives (9 credits)

Three (3) courses (9 credits.) must be selected from courses numbered 03, 04, 05, 06, or 07.

Those who have completed these core courses in master's degree programs may meet the core requirements by selecting courses, with the advice and approval of the advisor, from the specialized field.

Students must take and pass a Comprehensive Examination in the content area of Reading and Language.

Doctor of Education (Ed.D.)

To qualify for admission to a graduate program at the Doctor of Education level, an applicant must have earned a baccalaureate degree appropriate for his or her field of specialization from an accredited college or university and earned a master's degree from an accredited college or university with a cumulative grade point average of no less than 3.0. A personal interview with the Dean and/or the Academic Standards and Admissions Committee is also required.

Degree Requirements:

1. Complete a minimum of sixty (60) credits of required course work in the specified doctoral program. Students may request for transfer a maximum of twenty-four (24) credits of course work taken at another accredited institution. Students who have earned the C.A.G.S. in a pertinent field from this or another institution may transfer that credit into the program.
2. Complete the stipulated course requirements for the degree program at this university.
3. Complete all course requirements for the degree with a cumulative grade average of B or better. No additional course credits may be permitted in order to achieve the grade-point average of B or better required of the degree.
4. Satisfactorily complete the residency requirement.
5. Pass two(2) comprehensive examinations.
6. Satisfactorily complete and defend a dissertation as approved by the candidate's dissertation committee.
7. Complete the degree program within seven years from the date of admission.

Note: Students seeking Massachusetts certification as Supervisor/Director, Principal, or Consulting Teacher of Reading must also fulfill a special set of courses and practica. Students should consult with the Assistant Dean before beginning course work.

A. Leadership In Schooling Doctoral Program (Ed.D.)

Foundations of Education (6 credits)

01.645 Perspectives and Visions of Schooling I
01.646 Perspectives and Visions of Schooling II

Research and Evaluation (minimum 6 credits)

07.701 Seminar In Data Analysis
07.702 Seminar In Research Methodology and Design
07.703 Seminar in the Design of Research Projects (optional)

Field of Specialization Requirements (9 credits)

01.636 Sociology of Educational Communities
05.627 Managing Change and Conflicts in Schools
05.624 Instructional Leadership and School Reform

Dissertation (6 credits)

05.730 Advanced Research Seminar in Leadership In Schooling I
05.731 Advanced Research Seminar in Leadership In Schooling II

Electives (30 credits)

Thirty semester hours will be selected by the student with the advice and approval of the faculty advisor to provide an appropriate specialization in a professional field. For example, students in this program might take up to 18 hours in Supervision and Staff Development; Curriculum Theory and Design; Administration, Planning, and Policy, or Technology and Learning Environments.

B. Mathematics and Science Education Doctoral Program (Ed.D.)

Foundations of Education (9 credits) \

01.645 Perspectives and Visions of Schooling I
01.646 Perspectives and Visions of Schooling II
An additional 01 course

Research and Evaluation (minimum 9 credits.)

07.701 Seminar In Data Analysis
07.702 Seminar In Research Methodology and Design
An additional 07 course

Field of Specialization

1. Integration Requirements (minimum 9 credits)

04.622 Mathematics, Science and the Educated Mind
04.623 Moral and Ethical Issues in Science and Society
04.625 Issues in Science, Mathematics, and Technology Education

2. Concentration Requirements (minimum 12 credits)

04.626 Development of Concepts in Science or

04.627 Development of Concepts in Mathematics
04.628 Reasoning and Problem Solving in Science or
04.629 Reasoning and Problem Solving in Mathematics
Two (2) additional 04 courses

Dissertation (6 credits)

04.730 Advanced Research Seminar in Mathematics and Science Education I
04.731 Advanced Research Seminar in Mathematics and Science Education II

Electives (minimum 15 credits)

Must include 6 credits in collateral fields outside Education.

C. Language Arts and Literacy Education Doctoral Program (Ed.D.)

Foundations of Education (6 credits)

01.645 Perspectives and Visions of Schooling I
01.646 Perspectives and Visions of Schooling II

Research and Evaluation (minimum 6 credits)

07.701 Seminar In Data Analysis
07.702 Seminar In Research Methodology and Design
07.703 Seminar in the Design of Research Projects (optional)

Field of Specialization Requirements (9 credits)

06.673 Curriculum Design and Instruction for English/Language Arts
06.674 Curriculum Design and Instruction for English/Language Arts
06.670 Issues in Reading and Language Instruction

Dissertation (6 credits)

06.730 Advanced Research Seminar in Language Arts and Literacy I
06.731 Advanced Research Seminar in Language Arts and Literacy II

Electives (30 credits)

Thirty credits will be selected by the student with the advice and approval of the faculty advisor to provide an appropriate specialization in an academic or professional field.

Course Descriptions

01.600 Theories of Moral Education (3-0)3
Theories of moral education will be examined to determine differences in underlying assumptions and principles and to consider whether moral education is a proper function of the school.

01.609 Self-Perceptions and Education
Examination of self-referent thought and its influence on teaching and learning. Particular attention given to constructs relating to a sense of personal efficacy and its contribution to performance motivation. Implications for research, teaching, and program design will be discussed.

01.610 Theories of Learning (3-0)3
This course offers a detailed analysis of the major contemporary learning theories, both behavioral and cognitive. Areas to be covered include: attention, motivation, S-R paradigms, cognitive processes, Gestalt and field theories. Theorists studied: Bruner, Hebb, Kohlberg, Osgood, Piaget, Sears, Skinner, and Werner.

01.611 Cognition and Instruction (3-0)3
The reasoning and thinking processes and the importance of problem solving as methods of instruction.

01.612 Reasoning and Communication Processes (3-0)3
Using actual interpersonal experiences as well as educational and psychological research, this seminar explores patterns of communication in relation to inferred reasoning processes. At least one previous course in cognition or learning theory is recommended.

01.614 Issues in the History and Philosophy of American Education (3-0)3
An interdisciplinary analysis of the major development of American educational settings, including special interest group influence and the expanding social roles of schools.

01.615 Issues in the Philosophy of Education (3-0)3
Topics of contemporary concern will be examined with a view to their philosophical basis. Where applicable, views of the great philosophers will be examined relative to these topics.

01.616 Issues in Sociology of Education (3-0)3
An intensive analysis of selected issues and problems in the sociology of education.

01.617 Contemporary Issues in Education (3-0)3
This course is concerned with those philosophical disputes which have a direct relationship to the problems of education, namely, the school and social progress, the "open school," the validity of moral judgment, and education in the Third World.

01.619 Moral and Ethical Issues for the Science Curriculum (Grades 7-12) (3-0)3
Investigates the links that exist between science, technology and society, and evaluates the impact of these factors on science curricula.

01.624 John Dewey on Education: The Way Out of Educational Confusion (3-0)3
The aim of this course is to prompt a fresh look at John Dewey's educational theory and its relevance to those who work in schools today.

01.625 Organization of Schools and School Systems (3-0)3
The formal and informal social relationships of teachers, administrators, specialists, and pupils are examined for potential sources of role strain and role conflict.

01.626 Minority Issues in Public Education (3-0)3
Reviews common problems of minority groups from a national and local perspective. Addresses specific areas such as academic performance, social adjustment, cultural and language adaptations. Examines ways teachers and administrators can enhance the learning process for minority students.

01.635 Culture of the School (3-0)3
Considers schools as institutional "cultures" with their own unique norms, routines, traditions and regularities. Involves students in developing their own culturally grounded conception of how schools really work.

01.636 Sociology of Educational Communities (3-0)3
Examines the power structures of the community with special attention to the way in which persons responsible for schooling ought to relate to community organizations and work with them in developing policies that bear directly on the clients and constituents of schools.

01.641 Work, Technology, and Schooling (3-0)3
An examination of the ways in which various ideas of work discipline the goals of school, the methods of instruction and administrative structure.

01.642 Technology and American Culture (3-0)3
A study of the technological changes which have affected the way that goods have been manufactured, distributed, sold, and used in America since 1800.

01.645/646 Perspectives and Visions of Schooling I, II (6-0)6
Provides students a common reference for considering and understanding significant issues in education. Major concerns in schooling will be examined with a view to historical, sociological, and economic antecedents and implications for the future of education.

01.652 Current Perspectives on the Culture of the School (3-0)3
Examines patterns, regularities and influences of Teacher Education, administration, and cultures of teaching, the role of myth, discourse and diversity in changing schools.

01.701 Human Memory and Cognition (3-0)3
This course will cover the fundamentals of human memory and cognition. In addition to modern memory theory, the basic cognitive processes of perception, comprehension, believing, dreaming, imagination, and thinking will be explored.

01.702 Information Processing Theories of Human Performance (3-0)3
This course will examine in-depth information processing theories of learning and human performance. The function of schemas and information and memory structures will be examined as well as the areas of thinking, imagination, and problem solving.

02.550 Reading Education: Elementary (3-0)3
A critical analysis of fundamental issues and principles in the teaching of reading, including all phases of the elementary reading program; current materials and approaches for diagnosis and developmental teaching of reading.

02.551 Mathematics Education (3-0)3
New approaches in the curriculum and teaching of mathematics in the elementary school; analysis and use of current materials, multimedia approaches, and inductive and problem-solving techniques.

02.552 Social Studies and Science Education (3-0)3
Selection and organization of content for the teaching of social studies and science in the elementary school. Theories and strategies used in new programs, use of current materials, multimedia approaches, and the use of procedures to encourage thinking, discovering and creativity.

02.553 Language Arts Education (3-0)3
Approaches in the curriculum, teaching and assessment of the language arts in the elementary school will be analyzed, and various techniques of instruction will be studied.

02.554 Analysis of Teaching (3-0)3
The major classifications of learning outcomes are introduced and are interrelated with clearly defined performance objectives, teaching strategies, and evaluation techniques. (Development of the individual lesson plan. Classroom management and control.)

02.555 Literature for Children (3-0)3
An in-depth study of assorted genres of literature, the development of a literature program integrated with a variety of curriculum areas for elementary school-aged children in a multi-ethnic, multi-cultural environment.

02.556 Reading Disabilities (3-0)3
An advanced course in the analysis and remediation of reading disabilities which explores the use of critical diagnostic tools and specialized materials using the diagnostic-prescriptive method of teaching.

02.557 Reading Education: Middle/Secondary (3-0)3
The development of adult reading skills in the middle and secondary school by using these skills in the content areas. Individualizing content reading to suit the needs of students.

02.558 Measurement and Evaluation (I.C.) (3-0)3
The principles and procedures of measurement and evaluation essential to excellence in teaching. The main theme is that evaluation is an integral part of instructional design.

02.559 Developmental Psychology (3-0)3
A study of the concepts and methodologies of the major theoretical systems (Genetic-Structural — Neo-Behavioristic) in Developmental Psychology; and the application of these concepts in a variety of educational settings.

02.560 Curriculum Development: Middle/Secondary (3-0)3
Analysis, comparison, and evaluation of a variety of models for curriculum development; evaluation of present curricula in middle and secondary schools, and development of strategies for implementing curriculum reform.

02.561 Integration of Arts in the Curriculum (3-0)3
An in-depth analysis of the rationale for incorporating the arts into all content areas of the elementary and secondary school. Examination of methods and materials which facilitate this integration.

02.564 History of American Education (3-0)3
An analysis of the development of educational thought and practice in the United States within the context of American social, cultural, economic, and intellectual history.

02.565 Issues of Educating Minority Students in Schools (3-0)3
An interdisciplinary look at prejudice in our educational system. Provides students with the information they need to assist all children in their pursuit of the American dream.

02.XXX Curriculum and Teaching - Major Area: Secondary (3-0)3
An analysis of the content, methods, materials, and management techniques used in each major area of the secondary school. Simulation and self-evaluation of teaching. Observation and participation in secondary schools.

02.570 Curriculum and Teaching Art (5-12) (3-0)3
An analysis of the content, methods, materials, and management techniques used in the art classroom in grades 5-12. Simulation and self-evaluation of teaching. Observation and participation in selected art classrooms.

02.578.901 Teaching Elementary (12 credits) (12 0)12
Prerequisites: 02.550, 02.551, 02.552, 02.553, 02.554, 02.558, 02.559.
Full time apprentice teaching in the public elementary schools under the supervision of qualified teachers, principals, and faculty of the College of Education.

02.578.903 Teaching Elementary (6 credits) (6-0)6
Prerequisites: 02.550, 02.551, 02.552, 02.553, 02.554, 02.558, 02.559.
Full time apprentice teaching in the public elementary schools under the supervision of qualified teachers, principals, and faculty of the College of Education.

02.579 Seminar in Elementary Education (2-0)2
Discussion and analysis of the apprentice teaching experience.

02.XXX Teaching Major Area: Secondary (12-0)12
Prerequisites: 02.557, 02.558, 02.559, 02.XXX.
Full time apprentice teaching in the public secondary schools under the supervision of qualified teachers, department chairpersons, principals, and faculty of the College of Education.

02.581 Teaching Art: 5-12 (12-0)12
Prerequisites: 02.558, 02.561, 02.559, 02.XXX.
Full time apprentice teaching in the public schools under the supervision of qualified art teachers, department chairpersons, principals, and faculty of the College of Education.

02.595 Seminar in Art Education (3-0)3
Familiarization of the apprentice art teacher with the milieu of the school, its administration, activities, operations, services, personnel interactions, purposes and pressures.

02.596 Seminar in Middle/Secondary Education (3-0)3
Familiarization of the apprentice teacher with the middle and secondary school, its administration, activities, operations, services, personnel interactions, purposes and pressures.

02.500 Contemporary American Culture (3-0)3
Different aspects of the American Culture will be explored from its origin to the Twentieth Century.

02.501 Introduction to Second Language Instruction (3-0)3
A study of the general schools of thought that have formed the basis of teaching English as a Second Language. This course is designed to assist students in conceptualizing the foundations of second language acquisition.

02.502 Contemporary Issues and Mandates in the Education of Language Minority Children (3-0)3
Theories of learning in Bilingual Education will be presented. The rationale underlying Bilingual Education will be discussed. Policies and practices at State and Federal levels will be examined.

02.503 Methods of Second Language Instruction (3-0)3
Different approaches and teaching procedures in Second Language Instruction will be discussed as well as the methodological models of English as a Second Language instruction.

02.504 Curriculum Materials and Adaption ESL (3-0)3
Curriculum designs and instructional materials used in English as a Second Language will be examined.

02.505 Language Arts Instruction (3-0)3
Current approaches, methods and techniques for teaching Language Arts and their application to the use of English as a Second Language.

02.506 Teaching Conversation Skills in English (ESL) (3-0)3
Practical approaches will be explored to develop oral and communicative English skills of Bilingual students.

02.507 Dialogue Writing: Student/Teacher Interactions (ESL) (3-0)3
Reading and writing teaching theories as they relate to English as a Second Language will be analyzed and practically implemented.

02.508 Approaches to Second Language Testing and Assessment (3-0)3
Procedures to test and assess ESL-Bilingual students.

02.509 The Bilingual Child with Special Needs (3-0)3
Development of awareness, knowledge and skills for teaching culturally and/or linguistically different students who have moderate special needs.

02.510 Effective Teaching of Language Minority Students (3-0)3
Both the theoretical tenets and practical applications regarding the education of language minority students will be presented.

02.515 Field Work/Internship (3-0)3
On-site field experience in an ESL classroom (300 clock hours minimum), under qualified ESL teacher and university supervisor.

02.516 Culture of the Caribbean and Southeast Asia (3-0)3
An overview of the Caribbean and Southeast Asian peoples, which examines their linguistic, social, cultural, political, and economic traditions and influence.

02.517 Community Organization and Parental Participation (3-0)3
The aim is to prepare school personnel to work effectively with community groups and bilingual parent organizations.

02.518 Resources and Techniques - Bilingual Education (3-0)3
Evaluation, selection and/or adaptation of relevant bilingual education instructional materials will be a component of this course.

02.519 Methods of Teaching Content Area/ Language Acquisition (3-0)3
Bilingual foundations and strategies for native language and subject matter mastery.

02.520 Teaching Reading in English to Bilingual Students (3-0)3
Teacher strategies for LEP student mastery of native language skills.

02.521 Design/Adaptation of Curriculum and Instruction: Materials for Bilingual Education (3-0)
The major concepts of Bilingual curriculum development and adaptation will be discussed. Bilingual curricula will be analyzed in terms of subject matter, linguistic and cultural relevance.

02.522 Teaching Conversational Skills in English (3-0)3
Fundamental issues and principles in the teaching of reading and writing in English will be presented.

02.523 Dialogue Writing: Student/Teacher Interactions (Bilingual) (3-0)3
Reading and writing teaching theories as they relate to Bilingual issues will be analyzed and practically implemented.

02.524 Assessment/Diagnosis of Abilities and Achievements of Bilingual Students (3-0)3
Topics explored are linguistic and cultural factors involved in testing and teaching.

02.525 Field Work/Internship (3-0)
On site field experience in bilingual classroom (300 clock hours minimum), under a qualified Bilingual teacher and University Supervisor.

03.612 Computer Applications in the Classroom I (3-0)3
A general survey of classroom computer application: turnkey software applications, tool software, software selection, computer-video applications and telecommunications. Students will develop a computer-based lesson.

03.613 Computer Applications in the Classroom II (3-0)3
Concentration on the instructional applications of tool software: word-processing, spreadsheet, database, telecommunications and desktop publishing. Students will develop a software tool-based lesson.

03.616 Foundations of Thought and Philosophy in Educational Technology (3-0)3
This course will engage the student in study and reflection on the philosophical underpinnings of the technology movement especially as it may dictate direction in education.

03.620 Models of Integration of Technology in the Curriculum (3-0)3
Students will explore uses of instructional television, videodisc, computers and two-way cable systems to enhance their teaching in all curriculum areas. Curriculum development work will show due regard for an interdisciplinary approach. Students will develop a facility with technology as they learn to articulate appropriate integration in existing curriculum.

03.623 Use of Commercial TV for Instruction (3-0)3
This course will familiarize participants with the scope and nature of television as a cultural, educational and entertainment medium, review research on the role of television in relation to children's education and provide teachers with the skills and knowledge to use commercial television as a resource in the classroom.

03.651 Technology and Learning Environments (3-0)3
Curriculum policies and instructional issues in the uses of technology for instruction. Students will develop a model of the technological classroom.

03.652 Technology and Schools of the Future (3-0)3
Consideration of staffing, budgeting, policies, required curriculum design, physical plant, community partnerships and evaluation.

03.654 Technological Applications in the Curriculum (3-0)3
Review of the instructional power of various technologies for instruction and curriculum development: videodisc, interactive video, data communication, hardware/software/facility configuration.

03.655 Advanced Technological Applications in Education (3-0)3
A seminar dedicated to the development of fundable, technology-intensive projects, focusing on known principles of organizational development and proposal-writing. Interactive student-faculty collaboration encouraged.

03.660 Television: A Tool of Instruction (3-0)3
An historical review of the uses of television for instruction in the last 30 years. Instructional design, utilization in the classroom, and criteria for evaluation or programming being used in the schools now.

03.661 Curriculum Development for Technology-Based Instruction (3-0)3
Special emphasis on instructional design, scripting, formative evaluation; supplementary materials and experiences.

03.666 Distance Learning and Systems Design (3-0)3
A consideration of current distance learning programs and a review of research which may guide organizations in the design of new systems for specific populations.

03.668 International Trends in Educational Technology (3-0)3
An examination of instructional technology developments in selected foreign countries with a particular focus on implications for American practice and for international program development.

03.680 Research on the Educational Impact of Technology-Based Systems (3-0)3
An examination of the research and the direction it provides for selecting appropriate systems for learning.

03.690 Evaluation of Technological Curriculum (3-0)3
Formative and summative evaluation of television and computer software for instructional purposes.

03.691 Policy Issues Related to Technology (3-0)3
Consideration of the questions facing all school systems relative to access, equity, purpose, quality, uses and costs of integrating technology into the curriculum.

04.542 Collaboration: A Strategy for School Improvement (3-0)3
Designed to involve students in planning and experiencing collaborative processes and reflecting on personal and collective results.

04.543 Teaching of Thinking Program (3-0)3
This course is designed to assist all teachers (K-Adult Education) in developing systematic methods and techniques for the teaching of thinking. Recent trends in critical and creative thinking will be examined, and curriculum materials will be developed for use in participants' classrooms.

04.545 Museum Education at the Tsongas Industrial History Center (3-0)3
This course will deal entirely with nontraditional, non-classroom approaches to learning in a museum environment. Experiential learning, uses of artifacts, group activities, and individual activities will be used to construct time-restricted programs.

04.546 Production of Curriculum Materials at the Tsongas Center (3-0)3
This course will deal with the actual preparation of teaching materials, using electronic, photographic, and audio-visual equipment. Students will gain experience using several different personal computer systems.

04.547 Using Material Culture in the Classroom (3-0)3
Students will learn various methodologies for using a variety of material culture resources to teach topics in American history, science, literature or the arts. Techniques investigated will range from the use of small artifacts in the classroom, to using local history and community resources for projects outside the classroom.

04.548 Using Local History Resources to Teach the Industrial Development of American Society (3-0)3
Issues of the relationship of science and technology to the development of American culture can best be investigated using local history techniques. Students will learn various methodologies for using a variety of material culture resources to teach topics in the history of science, technology and industry.

04.553 Cross Disciplinary Approaches to Curriculum Development at the Tsongas Industrial History Center (3-0)3
Students will work directly with a Curriculum Specialist and teachers in residence at the Tsongas Center in the development of curricula in the broad area of industrial history with a topical focus on the industrial revolution in Lowell and other nineteenth-century industrial communities.

04.570 Trends and Issues in Pre-kindergarten-Primary Education (3-0)3
This course examines appropriate practice responsive to cognitive, cultural development of students in this age group.

04.571 Trends in Elementary Education (3-0)3
This course examines current topics and emerging trends in elementary education and their impact on teachers, schools, students and the public.

04.572 Middle School - Theory and Practice (3-0)3
This course provides an opportunity for educators to examine the physical, intellectual, emotional, and social aspects of the ten-to-fourteen-year-old child from a developmental perspective.

04.573 Trends in Secondary Education (3-0)3
This course examines current topics and emerging trends in secondary education and their impact on teachers, schools, students and the public.

04.575 Schools for the Future (3-0)3
What will they be like? How will the available technology be used? Will the purpose or support change? Students will be expected to design a model of the "school" for the next decade, with theoretical rationale and practical justification.

04.585 Early Childhood Education (3-0)3
Recent research and program planning requirements associated with implementing an early childhood program in schools and/or the community.

04.601/602/603 Issues in Science, Mathematics, and Educational Technology (3-0)3
One credit seminars on topics and problems of current interest or emerging importance in science and mathematics education.

04.605 Inquiry in Science Teaching (3-0)3
Consideration of experiential approaches to instruction that promote inquiry and conceptual understanding, including use of microcomputer-based activities and video technologies.

04.606 Science Curricula K-8 (3-0)3
Participants will analyze both the developmental and cyclical natures of primary science curricula development and implementation. A conceptual framework will emerge from the synthesis of existing information.

04.607 Science Curricula 7-12 (3-0)3
Investigation of science programs and curriculum design at secondary school levels, with particular emphasis on current literature and research.

04.608 Mathematics Curricula K-8 (3-0)3
Participants will analyze both the developmental and cyclical natures of elementary mathematics curricula development and implementation. A conceptual framework will emerge from the synthesis of existing information.

04.609 Mathematics Curricula 7-12 (3-0)3
Participants will analyze both the developmental and cyclical natures of secondary mathematics curricula development and implementation. A conceptual framework will emerge from the synthesis of existing information.

04.611 Processes and Settings for Mathematics Teaching (3-0)3
Models of mathematics and learning theories are related to the processes of conjecture and discovery. The roles of the microcomputer, software and authoring languages are presented in a problem solving mode.

04.613 Environmental Education for Elementary Schools (3-0)3
Presents an activity-based approach to multi-disciplinary environmental education. Participants develop unit plans and critique instructional activities.

04.621 Mathematical Standards and Connections through the Curriculum (3-0)3
Designed for middle school/junior high school teachers and supervisors to investigate rationale and implementation strategies for relating mathematics to other disciplines, emphasis on problem solving across curriculum areas.

04.622 Mathematics, Science, and the Educated Mind (3-0)3
Examination of the interaction of science and mathematics in the growth of knowledge, and current considerations of literacy.

04.623 Moral and Ethical Issues in Science and Society (3-0)3
Identification and study of fundamental ethical principles within various scientific, technological, and societal contexts, including application of concepts to classroom discourse.

04.624 Assessment in Science and Mathematics (3-0)3
(Note: Replaces 04.629.201 & 04.629.203)
An overview of major topics and issues related to testing, evaluation, and assessment, with application of related principles of research, curricular, and teaching decisions.

04.626 Development of Concepts in Science (3-0)3
Review of current and historical literature related to the philosophy and development of conflicted epistomological issues in science. Construction of a methodology for applying various conceptions to science teaching.

04.627 Development of Concepts in Mathematics (3-0)3
Participants will analyze the nature of mathematics content knowledge and the nature of mathematics process knowledge, as well as the nature and process of knowledge acquisition. A conceptual framework will emerge from the synthesis of existing information.

04.628 Reasoning and Problem Solving in Science (3-0)3
Analysis of thinking, critical thinking, problem solving, and reasoning as they are currently conceptualized in educational and psychological literature, with applications to science education.

04.629 Reasoning and Problem Solving in Mathematics Education (3-0)3
Participants will analyze current literature relating to those three areas. Synthesis of those data bases will provide participants with an understanding of their importance to curricula decisions.

04.630 Testing and Evaluation: Assessment Concerns for Science Education (3-0)3
Participants will investigate both testing and evaluation decisions that are associated with evaluation. Participants will have a working knowledge of the role evaluation has in curricula decisions.

04.631 Testing and Evaluation: Assessment Concerns for Mathematics Education (3-0)3
Participants will investigate both testing and evaluation decisions that are associated with evaluation. Participants will have a working knowledge of the role evaluation has in curricula decisions.

04.636 Theory and Research in Curriculum (3-0)3
A study of the nature of the educational experience and the creation of curricula. The contemporary theorists' views of content, concept, experience and curriculum development.

04.638 Curriculum Design: K-12 (3-0)3
A review of state mandates which, by law, shape the curriculum of the school. Examination of "new" curricula and their sources, as well as the development of a rationale for curriculum design and an evaluation of the personnel and techniques by which these curricula can be developed.

04.639 Planning Process (C & I) (3-0)3
Methods and theories of planning in educational and non-profit organizations. Setting goals and objectives, establishing priorities, undertaking a needs assessment for various kinds of short and long range planning.

04.640 Program Evaluation (3-0)3
The historical emergence of program evaluations will be considered, the evaluation tasks will be identified and the policy issues attendant to evaluation will be examined.

04.641 History of American Curriculum 1870-Present (3-0)3
Selected issues in the history of American curriculum will be discussed and analyzed in the light of current school curriculum concerns.

04.642 Politics of Curriculum Change: Control of Educational Programs (3-0)3
Analysis of various pressure groups that attempt to exert influence on the school curricula. Students will investigate the ideologies, mechanisms, and impacts of various political forces at the local, regional and national levels.

04.643 The Skillful Teacher (3-0)3
This course is designed to help teachers and educational leaders view teaching from a reflective stance. Teaching skills are identified from research on teaching; and video tapes of teaching are studied for examining the application of these skills in actual teaching practices.

04.644 Models of Teaching (3-0)3
Examination and mastery of alternative models of teaching; identification and evaluation of teaching tactics and strategies.

04.645 Teacher Morale, Job Satisfaction and Commitment (3-0)3
This course will enable students to analyze research from industry and education in order to understand the connections between productivity and commitment.

04.646 Influence of Gender and Class on Curriculum and Teaching: Teacher Morale and Job Satisfaction (3-0)3
This class explores the current research identifying hidden assumptions about gender which impinge on teaching as a career and on the curriculum of the schools.

04.649 Practicum Internship: Supervisor/ Director (3-0)3
Supervised clinical experience in a school under the direction of both the school administrator and a college faculty member. This course is for students seeking state certification.

04.650 Practicum: Curriculum and Instruction (3-0)3
Prerequisite: Permission of Chairperson of the Faculty.
Supervised clinical experience. An opportunity to apply the skills and knowledge of curriculum development and evaluation of instruction. Not for state Certification.

04.651 Program Development in Science Education. (3-0)3
Participants will develop a course of study with the advice of the course instructor. The course is intended to be an application of knowledge to an applied setting.

04.652. Program Development in Mathematics Education (3-0)3
Participants will develop a course of study with the advice of the course instructor. The course is intended to be an application of knowledge to an applied setting.

04.655 Directed Study in Curriculum and Instruction (3-0)3
Prerequisite: Permission of Chairperson of the Faculty.
Through frequent consultation with the instructor, the student will investigate and define a problem for research and will present the findings in a significant paper. The directed study may not be substituted for a required course.

04.656 Seminar in Curriculum and Instruction (Ed.M.) (3-0)3
Prerequisite: 04.637, 04.638, 04.639.
Contemporary research in the field and research being done on national and international curriculum projects. The student will apply his/her research knowledge to individual investigations and analyses to give evidence of expertise in his/her field.

04.587 Biotechnology: Applications for Secondary School Curriculum
Knowledge base of precollege teachers is expanded in current biotechnology topics, including: cell culture techniques, recombinant DNA, analytical and separation techniques, the human genome project, immunilogical techniques, and clinical aspects of biotechnology.

04.660 Secondary Schools in America
Examination of the history, current status, and future directions of schools in American society.

04.670 Issues in Curriculum and Instruction (3-0)3
Discussion of the origins of current problems in curriculum; the analysis of the viewpoints of leaders in curriculum reform; and the impact of new technologies on the direction of curriculum change are included.

04.671 Research Seminar I in Curriculum and Instruction (3-0)3
This course considers recent research in the relevant field and focuses on implications of the research for classroom and school practice. By this means it is expected that each student will identify an area of work for further study and original research for the qualifying paper.

04.672 Research Seminar II in Curriculum and Instruction (3-0)3
This course involves an in-depth search and review of the literature appropriate to the student's future research.

04.729 Directed Study in Mathematics or Science (3-0)3
Participants will develop a focused line of investigation with the supervision of a faculty member in the college. Approval of advisor is required.

04.730 Advanced Research Seminar in Mathematics and Science Education I (3-0)3
Consideration of topics and problems associated with literature reviews of participants in mathematics or science education. Prerequisite: Successful completion of qualifying examination.

04.731 Advanced Research Seminar in Mathematics and Science Education II (3-0)3
Consideration of topics and problems associated with research proposals of participants in mathematics and science education.
Prerequisite: 04.730.

05.620 Introduction to Educational and Human Service Administration (3-0)3
Explores how to be and what it means to be an administrator. "Grasps" of self in role and perception are related to ethical commitment.

05.622 Financial Aspects of Educational and Human Service Administration (3-0)3
Examines how moral and financial resources are marshaled to meet needs. Includes legal, economic and organizational analysis, program definition, budgeting, management and evaluation.

05.623 Legal Policy in Educational Administration (3-0)3
Understanding and research of issues and resolutions which define organizational activity in education. Ethical and creative practice of "preventive law."

05.624 Legal Policy in Human Service Administration (3-0)3
Understanding and research of issues and resolutions which define organizational activity in human services. Ethical and creative practice of "preventive law."

05.625 Personnel Administration and Educational Policy (3-0)3
Considers ideal "starting points" for a vision of personnel administration, including legal traditions, conscience and "shepherding," and their expression in a detailed model personnel "system."

05.626 Educational Response to Cultural Diversity (3-0)3
The role of schools in a culturally pluralistic industrial society. The response of educational institutions to diverse ethnic groups in earlier times. Recent legislation on public education will be examined during the latter part of the semester.

05.627 Citizen Participation in Education and Community Action Programs (3-0)3
Citizen participation increases in times of expectation; it declines in times of despair. What causes these periods of fluctuation? How and why are citizen groups organized? What gains can they make by organizing? What are the most productive techniques for capitalizing on this interest?

05.628 Parents and Schools (3-0)3
Understanding and improving the relationships between parents and schools can be an important factor in improving the quality of education. A study of pertinent theoretical and research literature as well as specific applied situations, such as effective approaches for involving "hard to reach" parents.

05.629 Politics of Education and Human Services (3-0)3
This course contrasts the tradition of keeping politics separate from education with the realities of the educational system, and it examines the political interplay at federal, state and local levels which shapes human services programs.

05.631 Human Service Administrator (3-0)3
Explores concepts through lives of persons who played administrative roles (biographies, literature, history) with attention to "turning points" (new hopes, places, organizations, perspectives).

05.639 Planning Process: Administration (3-0)3
Methods and theories of planning in educational and non-profit organizations. Setting goals and objectives, establishing priorities, undertaking a needs assessment for various kinds of short and long range planning.

05.640 Analysis of Educational and Human Service Organizations (3-0)3
An examination of various models of organizational analysis used to explain events and relation-

ships in educational and human service institutions. Each student will develop a case study and analysis using organizational theory.

05.641 Issues in Staff Development (3-0)3
Includes techniques for assessing staff needs,design of alternative programs to improve staff performance, strategies to ensure productive in-service education, and approaches to program evaluation.

05.642 Principles of Supervision (3-0)3
The interdisciplinary foundations of supervision: the function of theory, research on change, individual and group relationships in organizations, staff influence processes, talent utilization, and evaluation.

05.643 Principalship (3-0)3
The scope of the principal's role, including ethical dilemmas and practical realities, is examined by shadowing, case studies, simulation, literature review and written analyses. Participants identify and evaluate the effects of alternative styles.

05.644 Practicum: Educational Administration (3-0)3
Prerequisites: 05.620, 05.640, 05.639 and Permission of Coordinator.
Supervised clinical experience. Students acquire practical administrative experience in an educational setting under the direct supervision of both an educational administrator and a college faculty member.

05.645 Practicum: Human Services (3-0)3
Prerequisites: 05.620, 05.640, 05.639 and Permission of Coordinator.
Supervised clinical experience. Students acquire practical administrative experience in a hospital, social service agency or similar institution under the direct supervision of both an agency administrator and a college faculty member.

05.646 Practicum: School Principal (N-6) (3-0)3
Prerequisites: 05.620, 05.640, 05.643, 05.639 and Permission of Coordinator.
Supervised clinical experience in an elementary school under the direction of both the school administrator and a college faculty member.

05.647 Practicum: School Principal (5-9) (3-0)3
Prerequisites: 05.620, 05.640, 05.643, 05.639 and Permission of Coordinator.
Supervised clinical experience in a middle school under the direction of both the school administrator and a college faculty member.

05.648 Practicum: School Principal (9-12) (3-0)3
Prerequisites: 05.620, 05.643, 05.639 and Permission of Coordinator.
Supervised clinical experience in a secondary school under the direction of both the school administrator and a college faculty member.

05.649 Directed Study in Administration, Planning and Policy (3-0)3
Prerequisite: Permission of Faculty Chairperson.
Through frequent consultation with the instructor, the student will investigate and define a problem for research and will present the findings in a significant paper. The directed study may not be substituted for a required course.

05.650 Instructional Leadership and School Reform (3-0)3
Addresses the ways in which an instructional leader initiates changes in organizations - whether curricular or in the systems which make organizations function.

05.652 Managing Change and Conflict in Schools (3-0)3
Examines theories in the changing process, strategies for effective adoption and implementation of innovations and conflict resolution.

05.658 Role of Leadership in Contemporary Thought (Ed.D. only) (3-0)3
This seminar reviews works on leadership by major contemporary writers including Burns, Kellerman, Maccoby, and Peters & Waterman.

05.670 Research Seminar I in Administration, Planning and Policy (CAGS only) (3-0)3
Considers recent research in the relevant field and focuses on implications of the research for classroom and school practice. By this means it is expected that each student will identify an area of work for further study and original research for the qualifying paper.

05.671 Research Seminar II in Administration, Planning and Policy (CAGS only) (3-0)3
Involves an in-depth search and review of the literature appropriate to the student's future research.

05.729 Directed Study in Leadership in Schooling (3-0)3
Students will work on individually designed projects in leadership in schooling in close cooperation with a faculty member.

05.730 Advanced Research Seminar in Leadership in Schooling I (3-0)3
This seminar will consider recent research in the relevant field. The implications of the research for classroom and school practice will be its focus. Each student will identify an area of work for further study and original research for the dissertation.

05.731 Advanced Research Seminar in Leadership in Schooling II (3-0)3
The second seminar will involve an in-depth search and review of the literature appropriate to the student's planned research.

06.601 Developmental Reading: Elementary School (3-0)3
The acquisition and development of reading skills by children in the elementary school. Special emphasis will be placed on the analysis of new curricula, and on methods and materials designed to facilitate the child's reading development.

06.602 Developmental Reading: Secondary School (3-0)3
The continuum of reading skills from childhood through adulthood will be considered, with major emphasis on the acquisition and development of advanced reading skills by students in the secondary school.

06.603 Teaching Reading to Adults (3-0)3
This course examines recent research on adult learning and suggests a variety of effective instructional materials and strategies for teaching reading to adults in two-year colleges, in community settings, and in business and industry.

06.621 Literature for Children (3-0)3
The course will examine the importance of literature in the growth of the child, will consider ways of assisting children in developing a taste for the best literature, and will pursue strategies for organizing, projecting and evaluating a literature program.

06.622 Literature for Young Adults (3-0)3
The major emphasis of the course will be discussion and analysis of the goals of a literature curriculum and the exploration of various methods for achieving these goals.

06.624 Teaching Reading Comprehension (3-0)3
Examination of the comprehension process in light of current research. Students devise teaching learning strategies which positively influence the reading comprehension of children and young adults.

06.625 Teaching of Writing (3-0)3
This course reviews the research and literature on writing instruction, grades K through 14, and examines points of view, approaches, methodologies, and materials in the area.

06.626 Teaching Study Skills, Grades 4-14 (3-0)3
An examination of research and successful teaching practices in skills and processes associated with the acquisition, assimilation, and expression of new information and ideas.

06.627 Acquisition of Language (3-0)3
Investigates the process by which language is acquired. The pertinent research will be critiqued, methods of investigating and analyzing language studies and implications of language development in the acquisition of reading and language skills will be discussed.

06.628 Clinical Assessment of Reading and Language Disabilities (3-0)3
Prerequisites: 06.601, 06.602 (or their equivalents); A teaching certificate is required.
Selection and use of procedures to make an adequate clinical and educational diagnosis. Includes the assessment of function and dysfunction in factors associated with language development: receptive, expressive, writing, reading; and the administration and interpretation of individual and group tests of perceptual, motor, and conceptual functioning in reading and language.

06.629 Educational Treatment of Reading and Language Disabilities (3-0)3
Prerequisites: 06.628, teaching certificate.
Students develop realistic corrective programs based on the interpretation of academic, perceptual, motor, and language diagnostic assessment instruments. These programs will include selecting strategies of instruction and materials, and establishing a framework of time and evaluation.

06.630 Reading, Listening and Thinking (3-0)3
An exploration of research and theory in language-thought relationships with emphasis on the improvement of higher mental processes through instruction in listening and reading.

06.631 Organization and Supervision of Reading and Language Program (3-0)3
Organization and supervision of a reading-language program, evaluation of classroom instruction, selection of reading-language materials, coordination of the developmental program with remedial/corrective offerings, techniques of in-service education for various professional groups within a school system.

06.6XX Reading Institute (3-0)3
A one-week seminar concerning Reading, Language and Literacy Programs for the 90's. Noted educators will address issues in literature, diagnosis, computer instruction, adult literacy, program evaluation and language learning in school and non-school environments.

06.647 Directed Study in Reading and Language (Masters) (3-0)3
Prerequisite: Permission of Reading and Language Coordinator.
Through frequent consultation with the instructor, the student will investigate and define a problem for research in Reading and Language, and will present the findings in a significant paper. The directed study may not be substituted for a required course.

06.648 Practicum: Reading and Language Disabilities 3-6-9
Prerequisites: 06.628, 06.629, and Permission of Reading and Language Coordinator.
Supervised clinical experience in a school or clinical setting.
(Note: Open to matriculated students only.)

06.649 Seminar in Reading and Language (3-0)3
Prerequisite: Permission of Instructor.
A final course on the national and international research in reading and language and the pertinence and proposed implementation of research findings to instruction and the various roles of the reading supervisor or director.
(Note: Open to matriculated students only.)

06.650 Politics of Literacy (3-0)3
Literacy in the United States and the developed and developing nations of the world. Various techniques utilized in literacy instruction will be critiqued according to their success or failure from a political and social viewpoint.

06.651 Literacy Beyond the Schools (3-0)3
Adult literacy instruction and school drop-out literacy programs are among the topics discussed in this course. Students will consider multiple settings and strategies for literacy enhancement.

06.652 Seminar: Assessment of Writing
This course introduces students to the vocabulary, ideas and issues necessary for understanding the nature and purpose of assessment of writing.

06.655 History and Development of Reading Instruction in the United States (3-0)3
A retrospective study of the methodology and materials of reading instruction including a review of the social, economic and political climate which gave rise to the procedures utilized in each era and which, in turn, have influenced current theories and models of reading instruction.

06.656 Language Arts and Creativity (3-0)3
An exploration of the work on creativity, aspects of language arts and the relationships across these areas of study. Topics such as play, imagination, creative expression and problem-solving as well as attention to the dramatic arts and literature constitute the core of this course.

06.657 Seminar: Responses to Literature (3-0)3
An in-depth study of theory and research on the work in readers' responses to literature. Attention is given to past findings and methodologies as well as to future research in this area.

06.659 Seminar: Issues, Themes and Research in Children's and Young Adult Literature (3-0)3
Topics such as censorship, selection of materials, storytelling, language, imagination and human relations will be explored as they relate to children's literature to stimulate thinking about the importance of literature as well as to develop appreciation for literary works and language.

06.660 Technology in English/Language Arts and Literacy (3-0)3
Students will explore the potential of new technologies in language arts and literacy instruction. Word processing, data retrieval, organization and analysis of information, and individualized instruction will be examined.

06.661 Organization and Supervision of Language Arts and Literacy Programs (3-0)3
Several aspects of supervision such as supervisory roles and functions, models for supervision, supervision and educational improvement, and supervision and faculty development will be examined. How content and organization influence instruction, supervision and evaluation will also be considered.

06.670 Issues in Reading and Language Instruction (3-0)3
Prerequisite: Permission of Instructor.
Students will study such issues as the subskills vs. holistic theory of the reading process, spinoffs from the competency testing/basic skills trend, bilingualism as related to reading instruction, uses of electronic media in the schools, relationship of L.D. instruction to remedial reading.

06.671/672 Research Seminar in Reading and Language I, II (3-0)3
Prerequisite: Permission of Reading and Language Coordinator.
For CAGS students. Papers in areas related to problems in reading and language. An examination and analysis of current research at the national and international levels will be conducted, and methods of implementation and dissemination of pertinent results will be discussed.

06.673/674 Curriculum Design for English/Language Arts I, II (6-0)6
This course will examine past and contemporary designs for the language arts and literature curriculum, consider the issues associated with each, and develop an English language arts and literature program for schools of the future.

06.729 Directed Study in Language Arts and Literacy (Ed. D.) (3-0)3
Students will work on individually designed projects in language arts and literacy in close cooperation with a faculty member.

06.730 Advanced Research Seminar in Language Arts and Literacy I (3-0)3
This seminar will consider recent research in the relevant field. The implications of the research for classroom and school practice will be its focus. Each student will be able to identify an area of work for further study and original research for the dissertation.

06.731 Advanced Research Seminar in Language Arts and Literacy II (3-0)3
The second seminar will involve an in-depth search and review of the literature appropriate to the student's planned research.

07.640 Research Methods (3-0)3
The construction of statistically testable hypotheses, the design of research studies appropriate to the hypotheses, and the application of statistical tests appropriate to the research designs. Evaluation of published research in accordance with established criteria will be required.

07.649 Databases in Education (3-0)3
"Databases" (from file managers to utilities to management information systems to DBMS to expert systems) will be explored. Focus will be on various "databases" that educational administrators might need (or need access to) to promote educational productivity and learning and accurate and responsive management, planning, and evaluation information and knowledge.

07.650 Computer Literacy - Research Skills (3-0)3
In addition to acquiring an understanding of how computers work, knowledge of hardware and software and familiarity with computer terminology, participants will explore current instructional uses and the power and potential of the computer in developing thinking and problem-solving skills.

07.701 Seminar in Data Analysis (3-0)3
Prerequisite: An elementary statistics or research methods course satisfactory to the Program Faculty. This course covers in detail descriptive statistics, correlation, regression, probability theory, and comparative tests through analysis of variance.

07.702 Seminar in Research Methodology and Design (3-0)3
Prerequisite: 07.701 or acceptable substitute.
Methods of data collection suitable for answering a variety of educational research questions. Considers both qualitative and quantitative strategies for research and evaluation needs. Quantitative methodologies for descriptive, correlational and experimental questions will be emphasized.

07.703 Seminar in the Design of Research Projects (3-0)3
Students will search the literature in a field of their interest, develop research questions and formulate testable hypotheses for a suitable research plan. Methods of data collection and analysis will be discussed as they relate to the research questions and plan.

07.704 Qualitative Research Methods (3-0)3
This course concentrates on the use of qualitative methods for understanding situations and actions in learning contexts. Strategies for conducting qualitative studies are described and techniques for analyzing and disseminating findings are emphasized.

07.705 Survey Research Techniques and Strategies (3-0)3
Focusing on survey research methods, this course will familiarize students with the strategies, techniques, tactics, and issues in developing and administering questionnaires and interviews.

07.707 Writing for Professional Publication (3-0)3
This course will assist students: 1) to identify professional journals appropriate for publication of material in their fields, 2) to analyze the type of articles used, and 3) to prepare research, as well as information articles, clearly and concisely for publication.

08.651 History and Philosophy of Higher Education (3-0)3
Reviews the beginnings of higher education in Europe and the subsequent urgency and influences in establishing higher education in America.

08.659 Strategies for Instruction in Higher Education (3-0)3
A variety of theories, methods and techniques of teaching will be presented in order to familiarize instructors with the many options available to facilitate learning.

08.660 History of Minorities in Higher Education (3-0)3
Focuses on the entry, activities, problems and achievements of minorities in higher education, both past and present.

James B. Francis College of Engineering

Dean: Aldo M. Crugnola, A.B., Boston University; M.S., Northeastern University; Sc.D., Massachusetts Institute of Technology; P.E.
Assistant Dean: Louis J. Petrovic, B.S., Case Institute of Technology; M.S., Ph.D., Northwestern University; M.B.A. Boston College.
Associate to the Dean for Graduate Studies and Research: Sidney A. Bowhill, B.A., M.A., Ph.D., Cambridge University.

The education of engineers in state-of-the-art areas of advanced technology and the University's commitment to national and regional economic development are the major premises upon which the graduate programs in the College of Engineering are based. These programs are intended to produce engineers whose education not only develops expertise in the design, development and production of products, but also an understanding of the management involved in the creation of new products, companies and service organizations. Thus, the graduate programs in engineering are intended to educate engineers capable of keeping abreast with the rapidly changing technology that characterizes the high technology economy of the Northeast. The programs lead to degrees of Master of Science in Engineering, Master of Science, Doctor of Science, Doctor of Philosophy, and Doctor of Engineering.

Master of Science in Engineering (M.S. Eng.)

This degree is awarded in the following fields:

- Chemical Engineering
- Civil Engineering
  - Options – Environmental, Geotechnical, Geotechnical/Environmental, Structural, Transportation
- Materials Engineering
- Energy Engineering
  - Options – Fission, Fusion, Solar, Geothermal
- Electrical Engineering
  - Option – Electro-optics
- Systems Engineering
- Computer Engineering
- Plastics Engineering
  - Options – Plastic Materials, Design, Processing, Coatings & Adhesives, Fiber/Composite Materials

Note: A Manufacturing Systems Engineering option is open to all M.S. engineering students.

Master of Science (M.S.)

The M.S. is awarded in the following fields:

- Environmental Studies
- Plastics
- Work Environment
  - Options – Industrial Hygiene, Ergonomics

Master of Management Science (M.M.S.)

This degree is awarded in: Manufacturing Engineering

Doctor of Philosophy (Ph.D.)

The Doctor of Philosophy in Physics is awarded by the College of Arts and Sciences with the following options which are given in conjunction with the College of Engineering:

- Energy Engineering
- Engineering Mechanics

The Doctor of Philosophy in Chemistry is awarded by the College of Arts and Sciences with the following options which are given in conjunction with the College of Engineering:

- Environmental Studies
- Polymer Science/Plastics Engineering

Doctor of Science (Sc.D.)

A Doctor of Science degree is awarded in: Work Environment

Doctor of Engineering (D. Eng.)

Doctor of Engineering degrees are awarded in the following fields:

- Electrical Engineering
  - Electromagnetics, Systems, Computers, Semi-conductor and Microelectronics
- Mechanical Engineering
  - Dynamics and Solid Mechanics, Computational Methods in Thermo Fluids, Energy, and Composite Materials
- Plastics Engineering
  - Plastics Processing, Coatings, Synthetic Fibers and Composites, Plastic Materials and Additives

The Doctor of Engineering degree is a professional degree intended to equip students for the practice of engineering at the highest professional level and in organizations characterized by rapid change and ever increasing complexity.

The goal of the Doctor of Engineering program is to produce engineers who have the potential to become leaders in their organizations. To accomplish this, the program provides a doctoral level depth and breadth in a particular engineering discipline emphasizing design or clinical application. It combines this knowledge with basic courses in business and management. The technical components of the different programs are established by the faculties of the participating engineering departments. These are described in the various catalog sections.

The business, management and leadership component is common to all. The goal of this component is to supplement students' technical knowledge with fundamental business and management skills in analysis, problem solving, decision-making, planning and action implementation. This is accomplished with courses that have been specifically designed and tailored for the Engineering doctoral program by the College of Management Science.

The doctoral degree requires approximately 90-93 semester hours of study beyond the Bachelor of Science degree. A typical program is composed as follows:

Advanced Engineering Courses	44 credits
Dissertation	30 credits
Leadership/Management Core	16 credits
Doctor of Engineering Seminar	3 credits

The dissertation research involves working in leading edge design or development, typically in collaboration with faculty and practicing research engineers. The activity may be carried on in an industrial setting, government laboratory, or on campus.

Department of Chemical and Nuclear Engineering

Department Head and Graduate Coordinator of Energy Engineering Programs: José G. Martín, Professor; B.S. Mississippi State University; M.S., Ph.D., University of Wisconsin.
Executive Officer: H. William Flood, Associate Professor; B.S., Professional Degree (M.S. Equivalent) University of Missouri, Rolla; P.E. (Massachusetts).
Energy Engineering Program Coordinator: James P. Phelps, Professor; B.S., University of Maine; Ph.D., Michigan State University.
Graduate Coordinator of Chemical Engineering and Materials Engineering Programs: Thomas Vasilos, Professor; B.S., Brooklyn College; Sc.D., Massachusetts Institute of Technology.
Faculty: Francis J. Bonner, Professor; S.B., S.M., Massachusetts Institute of Technology; Ph.D., University of Delaware; Fil.Lic., Fil.Dr., University of Uppsala, Sweden; Gilbert J. Brown, Professor; B.S., Cornell University; M.S., Ph.D., Massachusetts Institute of Technology; Huan-Yang Chang, Professor; B.S., Southwest Associated University, China; M.S., University of Rhode Island; Ph.D., Iowa State University; Alfred A. Donatelli, Associate Professor; B.S., Lowell Technological Institute, Ph.D., Lehigh University; Charles J.

Higgins, Professor; B.S., Massachusetts Maritime Academy; B.S., Lowell Technological Institute; P.E. (Massachusetts); Carl W. Lawton, Assistant Professor; B.S., Purdue University; M.S., University of Connecticut (Chemical Engineering); M.S., University of Connecticut (Microbiology); Ph.D., University of Connecticut; Dominick A. Sama, Professor; S.B., S.M., Ph.D., Massachusetts Institute of Technology; James R. Sheff, Professor; B.S., University of Colorado; M.S., Ph.D., University of Washington; John W. Walkinshaw, Professor; B.S., M.S., Lowell Technological Institute; Ph.D., Victoria University, Manchester, England; John R. White, Assistant Professor; B.S., University of Lowell; M.S., Ph.D., University of Tennessee.

The Department's programs encompass both traditional areas of chemical and energy engineering and modern frontier areas such as computer aided process control, advanced engineered materials, biotechnology, alternate energy sources and utilization. The Department encourages cooperative university-wide efforts, especially in areas such as materials, productivity enhancement, and pollution control.

Combined B.S./M.S. Engineering Program – Chemical, Materials and Energy Engineering

A five-year B.S./M.S. Eng. program is available to undergraduates with a cumulative grade point average of at least 3.0 at the end of their junior year. See the front of the catalog for description.

Master of Science in Chemical Engineering Degree Program

The program in Chemical Engineering is designed to provide the opportunity for graduate students to study the fundamentals and applications of chemical engineering principles, and to carry out independent research.

Admission Requirements

The Department will consider students for enrollment in the Chemical Engineering program who have a Bachelor of Science degree in chemical engineering. Those with degrees in other areas, such as biology, chemistry, etc., are also admissible to the graduate program. However, during their course of study, they will be required to take the undergraduate courses in which they are deficient. It is highly recommended that such students complete four years of mathematics through differential equations, and one year each of organic chemistry and physical chemistry, prior to enrolling in the graduate program. Generally, such students require two to three years to complete the requirements for the M.S. Eng. degree in Chemical Engineering.

Advisors and Advisory Committee

The Program Coordinator will be the academic advisor for each student, to help remedy deficiencies in prerequisites, select electives of most value and plan the overall study program. The thesis advisor will chair the thesis advisory committee, which will guide the student in his or her thesis research and supervise the completion of thesis requirements.

Plan of Study

Each student shall file an approved plan of study with the Department Chairman and Graduate Coordinator. This form will contain a listing of the courses which will make up his or her program. Any changes must have the approval of the Department Area Graduate Committee and the Graduate Coordinator.

Credit Requirements

A minimum of 30 semester hours of graduate course work and thesis, excluding seminar, will be required for all graduate students enrolled in the Chemical Engineering Program.

Full-time students shall enroll in Seminar each semester. Part-time students shall enroll in at least two semesters of Seminar during the period of thesis research.

The following research and seminar courses are required:

10-701, 702	Chemical Engineering Program Research
10-601, 602	Chemical Engineering Seminar

Core Curriculum

Each student must take at least one course from four of the following groups of courses:

1.	10-503	Mass Transfer Operations I, or
	10-517	Mass Transfer Operations II
2.	10-509	Mathematical Applications in Chemical Engineering, or
	10-514	Advanced Process Optimization
3.	10-516	Micro Processor Control I, or
	10-518	Micro Processor Control II
4.	10-520	Advanced Chemical Engineering Thermodynamics, or
	10-529	Process Integration for the Efficient Use of Energy
5.	10-522	Computer-Aided Chemical Process Design
6.	10-528	Advanced Transport Phenomena

Thesis

Each student will be required to undertake a six semester-hour thesis. All students will defend their thesis when completed according to Graduate School regulations. During the period the student is enrolled in graduate thesis he or she will be required to submit to the staff of the Department a brief monthly report, showing progress of his or her thesis and approval by his or her advisor.

Master of Science in Materials Engineering Degree Program

This program provides opportunities for advanced study and research experience in materials engineering, with concentration in such areas as biomaterials, ceramics, composites, electronic materials, paper, or polymers.

Admission Requirements

Applicants for admission to this program should have a B.S. degree or equivalent in one of the following categories:

1. chemical engineering;
2. materials science and engineering, paper engineering or paper technology from other universities; or
3. related engineering and science, with correction of any deficiencies in undergraduate courses required during the graduate course of study.

Credit Requirements

A minimum of 30 graduate credits, excluding seminar, is required to fulfill the requirements of a master's degree in Materials Engineering. This should consist of a minimum of 12 credits in graduate Materials Engineering courses forming a coherent concentration in materials such as biomaterials, ceramics, composites, electronic materials, paper, and/or polymers. A student may choose to specialize in any area of materials engineering available in the College, with approval of the Departmental Area Graduate Committee, Graduate Coordinator, and Department Head. In addition, the student should take a minimum of 12 credits in approved technical electives, i.e., 500 series and selected 400 series courses in Chemical Engineering in conformance with Graduate School regulations. Suitable 500 level courses from other departments in the College may be substituted, with approval of the Departmental Area Graduate Committee, Graduate Coordinator and Department Head.

The following research and seminar courses are required:

10-703, 704	Materials Research
10-603, 604	Materials Seminar

Full-time students shall enroll in 10-603, 604 Materials Seminar for each semester. Part time students shall enroll in at least two semesters during the period of thesis research.

Plan of Study

Each student shall file an approved plan of study with the Department Head and Graduate Coordinator. This form will contain a listing of the courses which will make up the student's program. The plan and any subsequent changes must have the approval of the Department Graduate Area Committee, the Graduate Coordinator, and the Department Head.

Thesis

Each student will be required to undertake a six semester-hour thesis approved by the departmental Graduate Area Committee, Graduate Coordinator, and Department Head. During the period the student is enrolled in graduate thesis, the student will be required to submit to the Graduate Coordinator a brief monthly progress report approved by the student's advisor. All students will defend their completed theses according to Graduate School regulations.

Degree Programs in Energy Engineering

Research Interests

Research in energy engineering is carried out by several departments in the College of Engineering. Major engineering research facilities include a 1-Mw swimming pool research reactor and a 5 Mev van de Graaf accelerator. Within the University of Lowell Photovoltaic Program, there is a testing laboratory, a solar simulator, and photovoltaic arrays with a peak generating capacity of more than 10 kw. Extensive computing facilities support the ongoing work. Research interests in nuclear engineering include reactor physics methods development, radiation damage, cross section measurements, numerical analysis, fuel and waste management, and plant life extension. In solar thermal engineering, faculty interests include high concentration systems, power plant evaluation, passive solar systems, and solar fuels and chemicals. The photovoltaics effort includes work on design method development, solar/photovoltaic systems for grain drying, and solar spectrum splitting. Other interests include geothermal and wind energy utilization, and energy economics and safety.

Energy-related Degree Programs

Within the Department of Chemical and Nuclear Engineering, the Energy Engineering program offers a Master of Science in Engineering degree with two options: Nuclear Engineering and Solar Engineering. A Doctor of Engineering degree is offered in Mechanical Engineering with options in either Nuclear Engineering or Solar Engineering. In addition, a program offering a Doctor of Philosophy degree in Applied Physics with an option in Energy Engineering is offered jointly by the Department of Physics and the Energy Engineering program. For further information about either of these doctoral programs, please refer to the appropriate sections under Mechanical Engineering or Physics.

Master of Science in Energy Engineering

Graduate programs in Nuclear Engineering and Solar Engineering offer professional training at the master's degree level designed to prepare the student to perform state-of-the-art work on energy systems.

Credit Requirements and Thesis

Participants in the program may elect to follow a thesis or non-thesis option. The thesis option requires a minimum of 30 credit hours: 24 credit hours of course work plus six credit hours of thesis research. The non-thesis option requires a minimum of 33 credit hours: 30 credit hours of course work plus three credit hours of project work. A thesis must be defended in an oral examination conducted by the student's thesis committee.

Course Requirements

Students may choose to specialize in any area of energy interest in the College. Each student must take a series of core courses appropriate for the area of specialization. The exact make-up of the core curriculum will be guided and approved by the Graduate Committee of the Energy Engineering program. Two options are Nuclear Engineering and Solar Engineering. In the Nuclear option, concentration can be in either fission or fusion.

All students working toward the Master of Science degree in Energy Engineering must take the following courses:

24-504 Energy Engineering Workshop
24-509 System Dynamics
24-541 Fundamentals of Thermo Fluid Processes or
10-528 Advanced Transport Phenomena

The following courses are required for the Nuclear Option:

24-505 Reactor Physics
24-507 Reactor Engineering Analysis

For the Solar Option, the following are normally required:

24-521 Fundamentals of Solar Thermal Utilization
24-527 Solar Systems Engineering Commercial and Industrial

The remainder of the course requirements are to be made up of elective courses. In addition to the course and credit requirements described above, all students working toward the M.S. degree are required to participate in the Graduate Research Seminar, 24-501/2.

Course Descriptions

Courses which are primarily Chemical Engineering are given as 10-000*; primarily materials engineering, as 10-000*; and primarily energy engineering, as 24-000.

10-501 Paper Industry Process Analysis (3-0)3
Prerequisite: Permission of Instructor
Lectures dealing with the engineering processes of fiber separation from raw materials, fiber purification and mechanical processing of fiber and sheet formation. Chemical Engineering theory is applied to the analysis of these operations.

10-502 Principles of Chemical Engineering (3-0)3
Prerequisite: Permission of instructor (non-majors only)
An introduction to chemical process engineering for non-majors. Covers material and energy balances, thermal properties and flow in pipes. Processes are illustrated using a variety of home work assignments.

10-503 Mass Transfer Operations I (3-0)3
Prerequisite: Permission of instructor
Detailed coverage of separation processes of absorption and extraction. Mass transfer from microscopic and macroscopic points of view. Design principles for stagewise and differential columns.

10-504* Process Calculations of Paper and Pulp Processes (3-0)3
Prerequisite: Permission of instructor
Analysis of various chemical engineering processes encountered in the pulp and paper industry. The course provides a review of chemical engineering principles by application to the specific design and processes encountered in this industry.

10-506* Colloid and Interfacial Science and Engineering (3-0)3
Prerequisite: Permission of instructor
Unifying principles and the three main classes of colloids (dispersions, macromolecular, solutions and micelles) are considered. Topics covered include surface tension, work and energy, effect of surface curvature, zeta potential, surface activity and diverse applications of interest to chemical engineers.

10-509 Mathematical Applications in Chemical Engineering (3-0)3
Prerequisite: Permission of instructor
Classical and current mathematical methods are used to solve the equations that are developed in the modeling of chemical engineering processes.

10-514 Advanced Process Optimization (3-0)3
Prerequisite: Permission of instructor
An advanced study of modern optimization techniques having applications in process economics, process analysis, process dynamics, process kinetics and process design; methods such as linear,

non-linear, geometric, dynamic programmings, discrete and continuous maximum principles.

10-516 Microprocessor Control (3-0)3
Prerequisite: Permission of instructor
Single board computers and single chip controllers and how they are used in chemical process control.

10-517 Mass Transfer Operations II (3-0)3
Prerequisite: Permission of instructor
Fundamentals and modeling techniques for the separation process of distillation. Computer methods in designing and optimization. Energy conservation and sequencing of distillation columns.

10-518 Microprocessor Control II (3-0)3
Prerequisite: Permission of instructor
Programming methods for using minicomputers as process controllers; interfacing requirements and communications. Laboratory projects include both software and hardware components.

10-520 Advanced Thermodynamics (3-0)3
Prerequisite: Permission of instructor
The central theme of this course is the use of the Second Law of Thermodynamics to reduce energy consumption in operations and processes in the chemical industry. Lost work analysis techniques are developed for the evaluation of thermodynamic processes.

10-521 Introduction to Environmental Engineering (3-0)3
Prerequisite: Permission of instructor
Introduction to air, water, and toxic (hazardous) wastes. Defining the assessment parameters necessary to resolving environmental problems, process calculations on pollution abatement systems.

10-522 Computer-Aided Chemical Process Design (3-0)3
Prerequisite: Permission of instructor
Process synthesis definition, and characterization. Introduction to modular process simulation packages such as FLOWTRAN and ASPEN PLUS™. Recycle and tear stream analysis. Stream convergence. Unit operation models. Flowsheet manipulation. Data records and physical property estimation techniques.

10-523* Electronic Materials Processing (3-0)3
Prerequisite: Permission of instructor
Materials and processing methods in electronics and related industries; crystal growth, diffusion, etching, epitaxy, ion implantation, lithography, packaging and other topics.

10-525* Design and Use of Packaging Materials
(3-0)3
Prerequisite: Permission of instructor
A joint course taught in conjunction with the Department of Plastics Engineering that covers the use of forest product materials, plastics, metals and glass for use as packaging materials.

10-528 Advanced Transport Phenomena (3-0)3
Prerequisite: Permission of instructor
An advanced study of the mechanism of momentum, heat and mass transfer. The equations of continuity, motion and energy are used to examine steady and unsteady state processes. Considerable emphasis is placed upon solutions to problems.

10-529 Process Integration for the Efficient Use of Energy (3-0)3
Prerequisite: Permission of instructor
A critical study of the integration of heat and power requirements in chemical process plants. Topics to be studied include steam balances, heat pumps, heat exchangers, and heat recovery network design.

10-530 Advanced Control Strategies (3-0)3
Prerequisite: Permission of instructor
An introduction to computer control and to some of the common control strategies used in the design of complex chemical process control systems.

10-531* Survey of Ceramic Materials (3-0)3
Prerequisite: Permission of instructor
Structure, properties and applications of crystalline and vitreous ceramics and ceramic coating materials, Particular attention will be paid to the interplay of processing and properties.

10-532* Principles of Chemical Engineering II (3-0)3
Prerequisite: Permission of instructor
Continuation of Principals of Chemical Engineering including real gas relationships, humidity, energy balances, and the combined mass-energy balance systems.

10-533* Macromolecular Science (3-0)3
Prerequisite: Permission of instructor
This course emphasizes the relation of molecular and macroscopic properties and end-use to polymer synthesis and commercial manufacture. Pertinent fundamental principles are reviewed.

10-535* Bio-Materials and Bio-Processes (3-0)3
Prerequisite: Permission of instructor
This course emphasizes the relation of molecular and macroscopic properties and end-use of biomacromolecules in both materials and processes of chemical engineering interest. Compatibility with synthetic polymers is also considered.

10-601 Chemical Engineering Seminar (1-0)1

10-602 Chemical Engineering Seminar (1-0)1

10-603* Materials Engineering Seminar (1-0)1

10-604* Materials Engineering Seminar (1-0)1

10-651 Selected Topics in Chemical Engineering (3-0)3

10-652 Selected Topics in Chemical Engineering (3-0)3

10-653* Selected Topics in Materials Engineering (3-0)3

10-654* Selected Topics in Materials Engineering (3-0)3
Prerequisite: Permission of instructor
Advanced topics in the various fields of Materials Engineering. Content may vary from year to year to reflect contemporary applications of materials engineering.

10-743 Graduate Research in Chemical Engineering (0-9)3

10-746 Graduate Research in Chemical Engineering (0-18)6
Prerequisite: Permission of instructor
Every graduate student is required to perform research work done under the supervision of a senior chemical engineering faculty member in the Chemical Engineering Program. This thesis or project must be approved by an examining committee appointed by the Department Head.

10-743* Graduate Research in Materials Engineering (0-9)3

10-746* Graduate Research in Materials Engineering (0-18)6
Prerequisite: Permission of instructor
Every graduate student is required to perform research work done under the supervision of a senior chemical engineering faculty member in the Chemical Engineering Program. This thesis or project must be approved by an examining committee appointed by the Department Head.

10-751 Advanced Projects in Chemical Engineering (0-27)9
Prerequisite: Permission of department
Special projects laboratory undertaken by a student to expand his/her knowledge in specific fields not necessarily related to his/her thesis. Content of project, hours assigned and supervisor must be approved by the Department Head.

10-753* Advanced Projects in Materials Engineering (0-27)9
Prerequisite: Permission of department
Special projects laboratory undertaken by a student to expand his/her knowledge in specific fields not necessarily related to his/her thesis. Content of project, hours assigned and supervisor must be approved by the Department Head.

24-501, 24-502 Graduate Research Seminar (1-0)1
Presentation and discussion by faculty, invited speakers, and qualified graduate students of recent developments in the field of nuclear and solar engineering, energy policy and the financial and social costs of power. Required for all graduate students. Weekly meetings.

24-504 Energy Engineering Workshop (3-0)3
Prerequisite: Permission of instructor
A group/individual design project. The design effort will integrate many aspects of the student's engineering background, including design concepts, technical analyses, economic and safety considerations, etc. A formal report and oral presentation are required.

24-505 Reactor Physics (3-0)3
Prerequisite: Permission of instructor
Advanced treatment of several topics in reactor physics, including cross sections and processing methods, development of transport theory, reduction to diffusion theory, and analyses of analytical and numerical solutions of the resultant balance equations.

24-506 Special Topics in Reactor Physics (3-0)3
Prerequisite: Permission of instructor
Potential topics include nodal methods, perturbation theory, data sensitivity and uncertainty analysis, fuel management and core optimization methods, noise analysis, space-time kinetics, reactor control, reactor safety, etc. May be repeated since topics vary.

24-507 Reactor Engineering and Safety Analysis (3-0)3
Prerequisite: Permission of instructor
Modeling and analysis of reactor thermal-hydraulics and safety systems. Topics include nuclear heat generation and transport, single and two-phase flow, boiling crisis, and safety analysis.

24-508 Special Topics in Reactor Engineering (3-0)3
Prerequisite: Permission of instructor
Topics will deal primarily with reactor safety issues such as containment analysis, fission product release during accidents, probabilistic risk assessment, core concrete interactions, and standardized plant design.

24-509 System Dynamics (3-0)3
Prerequisite: Permission of instructor
Mathematics foundation using the state-variable approach. Topics include matrix methods, Laplace and Fourier transforms, transfer functions, frequency response and stability analyses, and distributed/lumped parameter systems. Applications to thermo-fluid systems.

24-510 Nuclear Fuel Cycle (3-0)3
Prerequisite: Permission of instructor
Discussion of the nuclear fuel cycle, including pre-irradiation, irradiation and post-irradiation steps of the fuel for nuclear reactors. Evaluation of the components of the cost of electricity produced by a nuclear reactor.

24-511 Advanced Reactor Concepts (3-0)
Prerequisite: 24-302 or 24-505
General characteristics. Breeding cycles and plutonium production, neutron balance, breeding ratio, and doubling time. Kinetics, control and safety, sodium void and Doppler coefficients. Design concepts.

24-512 Criticality Control (3-0)3
Prerequisite: Permission of instructor
Consideration of safe practices in transportation, storage, handling, and use of fissionable materials. Effects of moderators, reflectors, and geometrics in thermal, epi-thermal, and fast assemblies. Natural and engineered safeguards.

24-514 Waste Management (3-0)3
Prerequisite: Permission of instructor
History of nuclear waste disposal; engineering design of disposal systems. Present status of waste and the character and quantities of future wastes. Review of disposal concepts on a generic basis. The national plan for waste disposal.

24-516 Controlled Thermonuclear Fusion I (3-0)3
Prerequisite: Permission of instructor
Major approaches to controlled fusion. Fuel cycles. Sources and diagnostics. Confinement. Energy conversion: direct collection, electromagnetic-coupling and thermal cycles. Fusion blankets.

24-518 Neutron and Gamma Transport Theory (3-0)3
Prerequisite: Permission of instructor
Development and balance equations describing radiation transport. Analytical and numerical solution of the forward/adjoint integro-differential and integral Boltzmann equations. Emphasis on discrete ordinates and Monte Carlo methods as applied to radiation shielding.

24-519 Reactor Operator Training (0-6)3
Prerequisite: Permission of instructor
Training, including in-reactor experience and topical lectures, as given to Reactor Operator Trainees who will undergo Federal testing for a Reactor Operator License.

24-520 Reactor Operator Training (3-0)3
Prerequisite: Permission of instructor
Continuation of 24-519. Upon completion of this course, the student typically will be given a simulated Reactor Operator examination, including a written test, and oral test, an a controls manipulation test.

24-521 Fundamentals of Solar Energy Utilization (3-0)3
Prerequisite: Permission of instructor
Solar radiation in space and on the surface of the earth. Sunshape, intensity and flux: effect of location and orientation. Review of heat transfer. Opaque and transparent bodies. Characterization of solar collectors. A project is required.

24-522 Nuclear Materials (3-0)3
Prerequisite: Permission of instructor
Review of metals and metal oxide properties. Radiation damage in solids, plastics, ceramics, electronics, and graphite. Hardening, embrittlement, swelling, and creep in metals. Damage mechanisms. Shielding materials.

24-523 Numerical Methods in Engineering Analysis (3-0)3
Prerequisite: Permission of instructor
Finite dimensional vector spaces, matrix algebra, finite difference equations and matrix iterative techniques. Applications involving the neutron diffusion and heat conduction equations. Description of the Monte Carlo and response matrix methods.

24-524 Introduction to Solar Research (3-0)3
Prerequisite: 24-521 or Permission of instructor
Overview of solar thermal and photovoltaic projects and concepts. Solar systems as lossy networks. Lessons learned and potential for improvement. Fuels and chemicals. Direct conversion of solar energy. A project is required.

24-525 Controlled Thermonuclear Fusion II (3-0)3
Prerequisite: 24-516 or Permission of instructor
Introduction to plasma physics. Particle orbit theory. The kinetic equation. Macroscopic description-static problems, waves, and instabilities. The Vlasov equation-microscopic instabilities. Transport coefficients.

24-527 Solar Systems Engineering Commercial and Industrial (3-0)3
Prerequisite: Permission of instructor
Thermal network modeling, passive design tools, photovoltaic systems, solar cooling, daylighting, and economics. Experimental design and statistical inference.

24-529 Geothermal Energy (3-0)3
Prerequisite: Permission of instructor
Systematic study of geothermal energy resources and their distribution. Economics of geothermal applications. One type of geothermal plant will be studied from concept through operation.

24-531/2 Graduate Directed Studies (3-0)3
Prerequisite: Permission of instructor
Individual research projects in a variety of topics in nuclear, solar or general energy engineering and technology. Emphasis is on state-of-the-art research methods in the particular field of interest. May be repeated with consent of advisor.

24-533 Windmill Applications (3-0)3
Prerequisite: Permission of instructor
Introduction to the theory and engineering analysis of windmills. Included is consideration of the machine and machine types, the tower, energy conversion modes, and economic analysis. Consideration is given to the state-of-the-art, and existing machines and projects are reviewed.

24-535 Nuclear Instrumentation (1-3)3
Prerequisite: Permission of instructor
Electrical test and measurement techniques using oscilloscopes, function generators and multimeters. Construction and test of circuits in nuclear instrumentation.

24-537 Lifetime Extension of Nuclear Electric Plants (1-3)3
Prerequisite: Permission of instructor
Topics that are currently viewed as relevant to extending the operating lifetime of existing nuclear electric plants will be covered. Both technical aspects and governmental relicensing requirements will be included. The radiation damage occurring to various components including the vessel and its internals will be thoroughly examined.

24-743 to 24-749 Graduate Research
Prerequisite: Permission of instructor
Advanced research related to thesis work.

24-751/2 Graduate Projects (3-0)(3-0)6
Prerequisite: Permission of instructor
Advanced research project required of all students electing non-thesis option.

Department of Civil Engineering

Department Chairperson: Burton A. Segall, Professor, B.C.E., Polytechnic Institute of Brooklyn; M.S., M.P.H., University of North Carolina; Ph.D., New York University; P.E.
Graduate Coordinator: Donald G. Leitch, Professor; B.S., Lehigh University; M.S.,

Faculty: Frank P. Alberti, Associate Professor; B.S., Tufts University; M.S.C.E., Worcester Polytechnic Institute; M.S.M.E., Northeastern University; Ph.D., University of New Hampshire; P.E.; Clifford J. Bruell, Assistant Professor; B.S., Lowell Technological Institute; M.S., University of Lowell; Ph.D., University of Connecticut; Christopher Conley, Assistant Professor; B.S., University of Massachusetts; M.S., Ph. D., Cornell University; Mukti L. Das, Associate Professor; B.E., University of Calcutta; M.S., Ph.D., University of Massachusetts; P.E.; Susan Faraji, Assistant Professor; B.S., Arya-Mehr University of Technology; M.S., Northeastern University; Ph.D., University of Massachusetts; Nathan H. Gartner, Professor; B.S., M.S., Sc.D., Technion-Israel Institute of Technology; Dan S. Golomb, Associate Professor; M.Sc., Ph.D., Hebrew University, Jerusalem; William B. Moeller, Professor; B.S., Villanova University; M.S., Ph.D.,University of Connecticut; P.E.; Charles R. Ott, Professor; B.S., M.S., Ph.D., University of Washington; Samuel G. Paikowsky, Assistant Professor; B.S., M.S., Technion - Israel Institute of Technology, Sc.D., Massachusetts Institute of Technology; Louis C. Tartaglione, Associate Professor; B.S., Manhattan College; M.S., University of Connecticut, P.E.

Master of Science in Civil Engineering

Graduate study in Civil Engineering is an intensive design and planning oriented program of instruction at an advanced technical level. The program includes curricula in the areas of geotechnical engineering, structural engineering, transportation engineering, water resources and environmental engineering and a geotechnical/environmental option. The program permits students to construct, in consultation with their advisor, a plan of study which is balanced and provides for meeting individual goals and career objectives. The objectives and philosophy of each of the curricula and special requirements are outlined below.

Courses are scheduled in the late afternoon and evening to provide study opportunities for students with full-time employment. However, laboratory courses, and research and academic advisement are conducted during usual daytime hours.

General Requirements

Applicants who satisfy the Graduate School admission requirements will be assigned to a graduate faculty member who will act as their academic advisor. The Master of Science in Engineering degree requires the successful completion of 30 credit hours. This includes at least 24 hours in class and seminar work at the appropriate level, and at least six hours in preparation of a publishable thesis, or 27 credit hours of class-seminar work and at least three hours in preparation of a project report. A thesis is required of students receiving a teaching or research assistantship.

Those admitted to graduate study as non-degree students may apply for matriculated status. However, no more than 9 credits of work completed while on non-degree student status or transferred from another department or college will be used toward a degree. Matriculated status is preferred before initial registration and mandatory prior to registration for second semester courses. Faculty will review petitioner's performance in all courses attempted.

M.S. in Civil Engineering (Geotechnical Engineering Option)

The master's degree program in geotechnical engineering encompasses soil mechanics theory and its application to practical engineering problems in the fields of foundation and soil engineering. The course work emphasizes the engineering properties of soil, how soil properties are determined, and how they are used with soil mechanics theory in the solution of soil and foundation engineering problems.

Special Requirements

A bachelor's degree in Civil Engineering with at least one elementary course in each of soil mechanics, statics, strength of materials and fluid mechanics. Preparation of a publishable thesis is a requirement of the Geotechnical option.

Core Courses

All students will be required to complete:

14-531 Advanced Soil Mechanics

and any three of the following:

14-552 Theoretical Soil Mechanics
14-553 Advanced Foundation Engineering
14-534 Soil Dynamics and Earthquake Engineering
14-535 Rock Mechanics and Underground Structures
14-536 Soil Engineering
14-537 Experimental Soil Mechanics
14-538 Soil Behavior

Elective Courses

The student is required to complete at least four of the following courses:

14-504 Advanced Strength of Materials
14-505 Introduction to the Theory of Elasticity
14-532 Theoretical Soil Mechanics
14-534 Soil Dynamics and Earthquake Engineering
14-535 Rock Mechanics and Underground Structures
14-536 Soil Engineering
14-537 Experimental Soil Mechanics
14-538 Soil Behavior
14-550 Numerical Methods in Structural Engineering
14-562 Groundwater Hydrology
14-581 Engineering Systems Analysis
14-583 Stochastic Concepts

M.S. Civil Engineering (Structural Engineering Option)

This area of study provides students with advanced concepts and techniques which can be applied to the solution of complex structural engineering problems.

Special Requirements

A student seeking an M.S. Eng. in Structural Engineering must have a B.S. degree in engineering which includes senior level courses in analysis of statically indeterminate structures and in the design of steel and concrete structures. Students deficient in these areas must take these courses as prerequisites before they can take advanced courses.

Core Courses

Graduate programs in structural engineering will be developed to meet the needs of the individual. Selected program course content must be approved by the graduate coordinator and student's faculty advisor. Students must take or show proficiency in the following courses:

14-501 Engineering Mathematics I
14-504 Advanced Strength of Materials
14-551 Design of Steel Structures
or
14-552 Design of Reinforced Concrete Structures

M.S. in Civil Engineering (Environmental Engineering Option)

The program offers an opportunity to pursue a broad range of interests in the fields of environmental and water resources engineering. The course of study is designed to meet an individual student's interests and career goals. Programs consist of civil engineering courses in water and wastewater treatment, environmental chemistry, hydrology, hydraulics, air pollution control and courses from allied disciplines including the biological and health sciences, environmental studies, chemistry and work environment.

Special Requirements

Degree program students in environmental engineering and water resources must have a B.S. degree in engineering. Undergraduate course deficiencies in selected areas of study must be completed before taking advanced courses.

Core Courses

All students are required to complete or show proficiency in the following courses:

14-561 Physical and Chemical Treatment Processes
14-565 Industrial Waste Treatment Processes
14-567 Environmental Chemistry I
14-568 Environmental Chemistry II

Substitution of one or more of the above courses by an elective course is permitted if the program coordinator determines that a student has covered the required course material in previously taken graduate or undergraduate course work.

Elective Courses

Individual student programs consist of a complement of elective courses taken from the following list:

14-562 Groundwater Hydrology
14-564 Advanced Water Resources
14-570 Small and Alternative Waste Water Treatment
14-571 Surface Water Modelling
18-510 Water Resources Management
18-520 Environmental Impact Statements
18-522 Municipal Industrial & Hazardous Waste Management
18-523 Air Resources Management
18-527 Environmental Law
18-568 Environmental Laboratory
18-571 Air Pollution
18-572 Energy and the Environment
18-573 Air Pollution Laboratory
19-501 Industrial Hygiene
81-501 Wetlands Ecology
81-510 Limnology
84-519 Environmental Chemistry III (Marine Chemistry)

Elective Courses

Additional courses may be taken from the Civil Engineering, Mechanical Engineering, Mathematics, Work Environment, and Plastics Engineering departments and the College of Management Science.

M.S. in Civil Engineering (Transportation Engineering Option)

The program in Transportation Engineering offers courses encompassing planning, design and operations of multi-modal transportation facilities. It emphasizes the interdisciplinary nature of the subject, supplementing engineering concepts with techniques from management, economics, operations research and environmental studies. It is designed to provide the student with advanced technical knowledge for addressing transportation problems in a variety of practical situations. Specialization in a certain area can be achieved through thesis and project work.

Special Requirements

Students desiring to enter the graduate program in Transportation Engineering should have an undergraduate engineering degree, or be otherwise prepared in mathematics, physical science and engineering science. Students who have a science education but lack an engineering background may also be admitted, but may be required to take selected courses in engineering fundamentals before taking advanced courses.

Core Courses

A graduate plan of study will be determined to meet the professional needs of each student; however, at a minimum, each student is expected to have completed or show proficiency in the following courses:

14-441 Traffic Engineering
14-540 Urban Transportation Planning
14-581 Engineering Systems Analysis
14-583 Stochastic Concepts

Elective Courses

14-543 Transportation Systems Analysis
14-545 Public Transit Planning and Design
14-547 Airport Planning and Design
14-549 Traffic Flow Models

Elective courses from other appropriate disciplines such as engineering, management, and pure and applied science may be taken to form a coherent program in Transportation Engineering.

M.S. in Civil Engineering (Geotechnical / Environmental Option)

This program combines Geotechnical and Environmental Engineering, and is designed to provide the expertise required in Environmental Geotechnology.

Special Requirements

A bachelor's degree in Civil Engineering is required, with at least one elementary course each in soil mechanics, statics, fluid mechanics and chemistry. Undergraduate course deficiencies in selected areas must be completed before taking advanced courses.

Core Courses

14-531 Advanced Soil Mechanics
14-538 Soil Engineering
14-562 Groundwater Hydrology
14-567 Environmental Chemistry I
14-568 Environmental Chemistry II

Elective Courses

14-532 Theoretical Soil Mechanics
14-533 Advanced Foundation Engineering
14-534 Soil Dynamics and Earthquake Engineering
14-535 Rock Mechanics and Underground Construction
14-537 Experimental Soil Mechanics
14-538 Soil Behavior
14-561 Physical and Chemical Treatment Process Engineering 14-564 Advanced Water Resources
18-522 Municipal, Industrial and Hazardous Waste Management
18-527 Environmental Laws

The Five-Year B.S./M.S. Engineering Program

A five-year B.S./M.S. Eng. program is available to undergraduates with a cumulative grade point average of at least 3.0 at the end of their junior year. See the front of the catalog for a complete description.

Course Descriptions

14-501 Engineering Mathematics I (3-0)3
Series solutions to second order differential equations, Bessel and Legendre functions, vector analysis, differentiation formulas, line and surface integrals, and the divergence theorem.

14-504 Advanced Strength of Materials (3-0)3
Stress and strain at a point, curved beam theory, unsymmetrical bending, shear center, torsion of non-circular sections, theories of failure, introduction to the theory of elasticity.

14-505 Introduction to the Theory of Elasticity (3-0)3
Analysis of Cartesian tensors using indicial notation. Stress and strain concepts. Exact solutions to equations governing stress and displacement of elastic solids.

14-506 Numerical Methods in Engineering (3-0)3
Solution of nonlinear equations, solving sets of equations, difference operations, numerical differentiation and integration, characteristic-value problems, curve-fitting and approximation of functions.

14-531 Advanced Soil Mechanics (3-0)3
Basic theories of soil mechanics and their application under practical conditions. Basic strength principles and stress-strain behavior of clay, cohesionless and mixed types of soil.

14-532 Theoretical Soil Mechanics (3-0)3
Elementary theories important in soil mechanics. Theory of elasticity and elastic half space and its application to stress distribution and settlement problems. Use of limit analysis for lateral stresses, bearing capacity and stability. Theory of consolidation. Theory of flow through porous media and its application in flow nets.

14-533 Advanced Foundation Engineering (3-0)3
Design and analysis of shallow and deep foundations for various types of soil profiles. Foundations contiguous to existing structures, construction methods and case histories.

14-534 Soil Dynamics and Earthquake Engineering (3-0)3
Single and multi-degrees of freedom systems. Basic concepts of seismology, earthquake distribution, type, magnitude and intensity. Stress-strain soil behavior during transient and repeated loadings. Effect of earthquakes on soils strength degradation, and liquefaction, retaining structures and dams. Dynamically loaded foundations and earth structures.

14-535 Rock Mechanics and Underground Structures (3-0)3
Review of Engineering Geology; rock formations, rock types, weathering of rock, folds, faults and their mapping. Intact rock and rock mass description and engineering properties. Stability and rock slopes. Underground structures in rock and soil.

14-536 Soil Engineering (3-0)3
The study of soil as an engineering material, and its use in earth dams, road embankments, flow control, and compacted fills. Stability of natural slopes, soil reinforcement and stabilization.

14-537 Experimental Soil Mechanics (3-0)3
Application of testing procedures to the evaluation of soil type and engineering properties. Testing for classification, permeability, consolidation, direct and triaxial shear and field parameters. The technical procedures are followed by data analysis, evaluation and presentation. Critical examination of standard testing procedures, evaluation of engineering parameters, error estimation and research devices.

14-538 Soil Behavior (3-0)3
In-depth study of soil properties and behavior under loading and shear. Includes: soil mineralogy, formation and composition, soil fabric and structure and their relation to engineering properties. Soil behavior under isotropic and Ko consolidation. Principles of behavior during shear, triaxial compression and extension. Generalized behavior.

14-539 Structural Pavement Design (3-0)3
Analysis of pavement loads and stresses, pavement material characterization, design of flexible and rigid highway and airport pavements, pavement evaluation and rehabilitation.

14-540 Urban Transportation Planning (3-0)3
Basic principles of urban transportation planning. Characteristics of urban travel; characteristics of urban transportation systems. Data collection; analysis of travel demand; analysis of system performance. Project evaluation; project implementation.

14-543 Transportation Systems Analysis (3-0)3
Demand, supply and equilibrium in multimodal transportation systems. Analysis of transportation decisions; searching for optimal design strategies.

14-545 Public Transit Planning and Design (3-0)3
Role of public transit; transit system design and operating characteristics including accessibility, speed, capacity, headway and terminal layout and operation; developments in transit technology.

14-547 Airport Planning and Design (3-0)3
Planning, locating and designing airport facilities; airport financing; air traffic control; aircraft characteristics; estimation of aeronautical demand; site selection and environmental effects; planning and design of terminals and heliports.

14-549 Traffic Flow Models (3-0)3
Microscopic and macroscopic models of traffic flows on transportation facilities. Levels of service and quality of service as influenced by physical design aspects and operational control measures.

14-551 Design of Steel Structures (3-0)3
Elastic and plastic design of structural steel systems, residual stresses, local buckling, beam-columns, torsion and biaxial bending, composite steel-concrete members, load and resistance factor design.

14-552 Design of Reinforced Concrete Structures (3-0)3
Review of USD and WSD methods for flexure and shear, anchorage, torsion, and deep beams, slender columns and beam-columns, deflections, slabs and walls.

14-553 Timber Structures (3-0)3
Design of timber members in tension, compression and bending; design of connections, wood trusses and frames.

14-554 Prestressed Concrete Design (3-0)3
An introductory course in the analysis and design of prestressed concrete structures. ACI/PCI Code applications.

14-556 Finite Element Analysis (3-0)3
Direct and variational methods are used to derive equations for structural elements. Static and dynamic problems are analyzed.

14-557 Structural Dynamics (3-0)3
Analysis of typical structures subjected to dynamic force or ground excitation using direct integration of equations of motion, modal analysis and approximate methods.

14-558 Experimental Methods (3-0)3
Topics covered include: Modelling theory and similitude requirements; model fabrication and loading, experimental stress analysis, transducer theory and use, and computer-based data acquisition and control.

14-559 Advanced Projects in Structural Engineering (3-0)3
Studies of topics of special interest and need of the students in structural analysis and/or design.

14-561 Physical Chemical Treatment Processes (3-0)3
Theories of physical chemical treatment processes and the laboratory (or pilot plant) techniques necessary to obtain design. Treatment processes for natural waters, domestic wastes, and industrial wastes.

14-562 Groundwater Hydrology (3-0)3
Well hydraulics for the analysis of groundwater movement. A review of the processes of diffusion, dispersion, sorption, and retardation as related to the fate and transport of organic contaminants in groundwater systems. Groundwater contamination remediation techniques are discussed.

14-563 Hydraulics of Open Channels (3-0)3
Problems of varied or non-uniform flow in open channels, surface profile determinations, hydraulics of reservoirs and treatment works under unsteady flow conditions. Primary interest on applications and typical cases.

14-564 Advanced Water Resources Engineering (3-0)3
Advanced course in civil engineering hydraulics and hydrology. Development of skills and familiarization with pressure conduit and open channel hydraulic models and Corps of Engineer and Soil Conservation Services, hydrologic programs.

14-565 Industrial Waste Treatment Processes (3-0)3
An introduction to the unit operations most commonly encountered in industrial waste treatment. Specific industrial applications will be stressed after an understanding of each unit operation has been developed.

14-566 Biological Waste Treatment Processes (3-0)3
Selection and design of aerobic and anaerobic biological waste treatment processes. Techniques for generating design data and prediction of process efficiency. Laboratory exercises including bench scale studies.

14-567 Environmental Chemistry I (3-0)3
The chemistry of natural waters and of water and wastewater treatment. Dilute aqueous solution chemistry of acid-base reactions and complex formation. Emphasizes chemical equilibrium. Foundation for environmental studies.

14-568 Environmental Chemistry II (3-0)
Environmental transport of organic chemicals and atmospheric gases in air, water and soil systems. The kinetics of mass transfer from an equilibrium perspective across environmental interfaces.

14-569 Advanced Projects in Water Resources (3-0)3
Studies of topics of special interest and need of students in environmental engineering and water resources design.

14-570 Small and Alternative Waste Water Treatment (3-0)3
A design oriented course covering subsurface disposal, surface systems disposal, nonconventional collection systems and planning approaches.

14-571 Surface Water Modelling
Problems of flow and water quality will be examined in river, lake and estuarine systems. Conceptual and computer models will be developed and used for surface water system evalution.

14-581 Engineering Systems Analysis (3-0)3
Methods of operations research, management science and economic analysis used in the design, planning and managing of engineering systems.

14-583 Stochastic Concepts (3-0)3
Effects of uncertainty in engineering design and decision making. Emphasis on practical applications of mathematical principles and tools of probability and statistics to problems in civil engineering.

14-651 Special Topics in Civil Engineering (3-0)3
Course content and credits to be arranged with instructor who agrees to direct the student.

14-690 Independent Project in Civil Engineering (satisfies project option)

14-743,6 Graduate Thesis in Civil Engineering (satisfies thesis option)

Program in Environmental Studies (Civil Engineering)

Graduate Coordinator: William B. Moeller, Professor of Civil Engineering; B.S., Villanova University; M.S., Ph.D., University of Connecticut.

Faculty Associated with the Environmental Studies Program: Eugene F. Barry, Professor of Chemistry; B.S., Villanova University; Ph.D., University of Rhode Island; John I. Bruce, Professor of Biological Sciences; B.S., Morgan State College; M.S., Ph.D., Howard University; Clifford J. Bruell, Assistant Professor of Civil Engineering, B.S., Lowell Technological Institute; M.S., University of Lowell; Ph.D., University of Connecticut; Michael J. Ellenbecker, Professor of Work Environment; B.S.E.E., University of Minnesota; M.S.E.E., University of Wisconsin; M.S., Sc.D., Harvard University; Dan S. Golomb, Associate Professor of Civil Engineering, M.Sc., Ph.D., Hebrew University, Jerusalem; Jesse Y. Harris, Professor of Physics/Radiological Sciences; B.S., M.S., Ph.D., Rutgers-The State University; Charles Levenstein, Professor of Work Environment, B.S., New York State School of Industrial and Labor Relations; M.S., Harvard School of Public Health; Ph.D., Massachusetts Institute of Technology; John C. Mallett, Professor of Biological Sciences; B.S., College of the Holy Cross; M.S., Ph.D., University of Rhode Island; Charles R. Ott, Professor of Civil Engineering; B.S., M.S., Ph.D., University of Washington; Donald S. Pottle, Associate Professor of Industrial Technology; B.S., M.S., Northeastern University, P.E.; David K. Ryan, Assistant Professor of Chemistry, B.S., Lemoyne College, Ph.D., University of New Hampshire; Burton A. Segall, Professor of Civil Engineering; B.C.E., Polytechnic Institute of Brooklyn; M.S., M.P.H., University of North Carolina; Ph.D., New York University, P.E.

Master of Science Degree Program

This interdisciplinary program offers a Master of Science in Environmental Studies with a thesis or a non-thesis track. Enrollment in the program is open to individuals with a baccalaureate degree in technology, biology or a physical science. Others may be admitted with the approval of the Program Coordinator. Such students may make up course prerequisite deficiencies while in the program, although those credits will not count toward the total required for the master's degree. Frequently, students entering the program are required to take a number of undergraduate courses to develop analytical skills and to prepare for advanced level course work. Undergraduate courses may include calculus, statistics, chemistry, computer programming or courses designed to develop problem-solving techniques. Course requirements are determined by discussion with the Program Coordinator.

The thesis track requires completion of a program of study involving a minimum of 27 credits of core courses and electives, and 6 credits of thesis, consisting of laboratory research or scholarly investigation, for a total of 33 credits. Students may only register for thesis research with the prior approval of a thesis advisor. The thesis work is to be guided by a principal advisor who is a member of the University of Lowell faculty and by two additional committee members, at least one of whom must be a member of the faculty. Committee selection and the thesis topic are subject to the approval of the Program Coordinator.

The non-thesis track requires completion of a program of study involving 33 credts of core courses and electives.

All individual programs of study must include 9 credits of core courses in water resource management, air resource management and environmental law.

Core Courses

18-510 Water Resources Management
18-527 Environmental Law
18-523 Air Resources Management
or
18-571 Air Pollution and Its Control

Elective Courses

Individual student programs consist of a complement of elective courses usually taken from the following list:

14-562 Groundwater Hydrology
14-564 Advanced Water Resources
14-565 Industrial Waste Treatment
14-570 Small and Alternative Wastewater Treatment
14-571 Surface Water Modelling
18-510 Water Resources Management
18-520 Environmental Impact Statements
18-522 Municipal, Industrial & Hazardous Waste Management
18-523 Air Resources Management
18-525 Epidemiology for Environmental Studies
18-530 Problems in Environmental Health
18-568 Environmental Chemistry Laboratory
18-571 Air Pollution and Its Control
18-572 Energy and the Environment
18-573 Air Pollution Laboratory
18-701 Graduate Research in Environmental Studies
19-501 Industrial Hygiene
20-570 Operation and Maintenance in Wastewater Treatment
81-501 Wetlands Ecology
81-510 Limnology
84-519 Environmental Chemistry III

Ph.D. Program in Chemistry – Environmental Studies Option

A Ph.D. in Chemistry with an option in Environmental Studies is offered jointly by the Department of Chemistry and the Department of Civil Engineering. The program is described in detail in the Chemistry Department section of this catalog.

Course Descriptions

18-510 Water Resources Management (3-0)3
Concepts and methodologies of hydrology, constraints and objectives of water resources management, and the interrelationship between hydrologic and managerial components of water resource issues. Case studies are reviewed and discussed.

18-520 Environmental Impact Statements (3-0)3
Methodology for preparing environmental impact statements. Required information and methods of writing the statements for both federal and state agencies. Current and future review systems are discussed.

18-522 Municipal, Industrial and Hazardous Waste Management (3-0)3
Characterization, handling and disposal of municipal, industrial and hazardous wastes. Technologies such as landfills, recycling, incineration and composting are examined.

18-523 Air Resources Management (3-0)3
Air pollutants, their sources, emission rates, ambient concentrations, effects on health, animals and vegetation including aquatic life. The Clean Air Act, National Ambient Air Quality Standards, New Source Performance Standards, Prevention of Significant Deterioration, Monitoring at emission sources and in the ambient; exceedances and enforcement. Air pollution modeling as a tool of permitting and enforcement. Emission control

technologies and strategies. Local, regional and global air resources management.

18-525 Epidemiology for Environmental Studies (3-0)3
The study of the distribution and determinants of disease in human population and how these diseases are disseminated by environmental changes. The methods used in conducting epidemiological investigations including descriptive analytical and experimental studies, patient care and cohort studies.

18-527 Environmental Laws (3-0)3
The large body of law which has developed since the early 1960's is examined in considerable detail. Federal laws relating to the environment, particularly with the Environmental Protection Agency and the Occupational Safety and Health Acts. Local laws and ordinances are discussed where pertinent.

18-530 Problems in Environmental Health (3-0)3
Relationships between environmental health and human activities. The impact of science and technological advances on the environmental health of a community. Dangers arising from air pollution, contamination of water supplies, sewage and industrial wastes, radioactive substances, insecticides and herbicides, contamination of food by chemical and biological agents, occupational hazards, and solid waste disposal and its deterioration of recreation waters.

18-568 Environmental Chemistry Laboratory (3-0)3
Wet chemistry and instrumental techniques for the analysis of waters and wastewaters. Instrumental methods include atomic absorption spectroscopy, gas chromatography and potentiometric methods.

18-571 Air Pollution and Its Control (3-0)3
Air pollutants: their sources, emission rates, ambient concentrations and trends. National and international standards for emissions and ambient concentrations. Air pollution meteorology: atmospheric structure and dynamics. Air pollutant dispersion and transport. Photo-oxidant pollutants: precursors and products. Particular matter: primary and secondary particles, their dispersion, transport and deposition on a local and regional scale, including regional haze (visibility impairment). Acid deposition: precursors and products, their transport, dispersion, dry and wet deposition. Global air pollution, e.g. stratospheric ozone depletion and greenhouse effect.

18-572 Energy and the Environment (3-0)3
Laws that govern the conversion of energy from one form to another. Flow of energy in our present industrial society from extraction through transport and conversion to end use. Electricity: generation from fossil fuel, nuclear, hydro, solar and other sources; its distribution and end use. Air, water and soil pollution from all sources of energy on a local, regional and global scale. Amelioration of environmental effects by emission control, fuel switching, renewable energy and conservation.

18-573 Air Pollution Laboratory (3-0)3
Instruments and apparatus applied to monitoring and chemical analysis of air pollutants, gaseous and particles (aerosols). Physico-chemical fundaments of air pollutant monitoring and analysis. Standard monitoring of "criteria" pollutants (CO, O_3, NO_x, SO_2, total hydrocarbons, size-fractioned particles) and other pollutants (lead and other metal vapors, speciated organic compounds). Analytical techniques (gas chromatography, chemiluminescence, mass-spectrometry, flame ionization, atomic and molecular emission and absorption spectroscopy). Data collection, archiving and analysis. Use of data in air pollution modeling.

Department of Electrical Engineering

Department Head: Bodo W. Reinisch, Professor; M.S., University of Freiburg; Ph.D., Lowell Technological Institute.
M.S. Eng. Program Coordinator: F. Ross Holmstrom, Professor; B.S., University of Washington; M.S., Ph.D., Stanford University.
Doctoral Program Coordinator: Dikshitulu Kalluri, Professor; B.E., Andhra University; M.S., University of Wisconsin; D.I.I.Sc., Indian Institute of Science; Ph.D., University of Kansas.
Faculty: Francesco L. Bacchialoni, Associate Professor; Dott. Ing., University of Genoa; Roger H. Baumann, Professor; S.B., S.M., Massachusetts Institute of Technology; Sc.D., University of Paris; Sidney A. Bowhill, Professor; B.A., M.A., Ph.D., Downing College, Cambridge University; Ronald D. Brunelle, Associate Professor; B.S., M.S., Lowell Technological Institute; P.E.; George P. Cheney, Associate Professor; B.S., M.S., Lowell Technological Institute; Donn A. Clark, Associate Professor; B.S., Pennsylvania State University; M.S., Northeastern University; P.E.; Robert J. Dirkman, Associate Professor; B.S., Tufts University; S.M., Massachusetts Institute of Technology; Michael A. Fiddy, Associate Professor; B.Sc., Ph.D., University of London; Alexander Khazan, Professor; M.S., Moscow University; Ph.D., Moscow Engineering Institute; Venkatarama Krishnan, Professor; B.S., Banaras Hindu University; B.S., Madras University; M.S.E., Princeton University; Ph.D., University of Pennsylvania; Walter S. Kuklinski, Associate Professor; B.S., Lowell Technological Institute; M.S., Ph.D., University of Rhode Island; E. Russell Laste, Jr., Professor; B.S., M.S., Northeastern University; Ph.D., Worcester Polytechnic Institute; J. Robert A. Lemieux, Associate Professor; B.S., M.S., Lowell Technological Institute; John P. Leonard, Associate Professor; B.S., Lowell Technological Institute; M.S., Northeastern University; Jerome M. Lavine, Associate Professor; A.B., A.M., Ph.D., Harvard University; Joseph B. Milstein, Associate Professor; B.S., California Institute of Technology; M.B.A., University of Maryland; Ph.D., Polytechnic Institute of New York; Samson Mil'shtein, Professor; B.S., M.S., State University of Odessa, U.S.S.R.; Ph.D., University of Jerusalem, Israel; Paul J. Murphy, Associate Professor; S.B., S.M., Massachusetts Institute of Technology; P.E.; Robert E. Parkin, Associate Professor; B.Sc.(Eng.), University of London; D.I.C., Ph.D., Imperial College, University of London; Martin A. Patt, Associate Professor; B.S., Northeastern University; S.M., Massachusetts Institute of Technology; Kanti Prasad, Associate Professor; B.Sc., Agra University; B.E., University of Roorkee; Ph.D., University of South Carolina; P.E.; James Rome, Associate Professor; B.S., M.S., University of Michigan; Ph.D., University of Pennsylvania; Charles R. Rupp, Associate Professor; B.S., Rose Hulman Institute of Technology; M.S.E.E., M.S.C.S., Rensselaer Polytechnic Institute; Ph.D., University of Massachusetts; Ziyad M. Salameh, Associate Professor; B.S., Moscow Power Engineering Institute, U.S.S.R.; M.S., Ph.D., University of Michigan; Gary S. Sales, Associate Professor; B.S., Brooklyn College; M.S., Ph.D., Pennsylvania State University; Stephen J. Spurk, Associate Professor; B.S., Merrimack College; M.S., University of New Hampshire; Rao C. Tenneti, Associate Professor; B.S., Andhra University; B.S., M.E., Ph.D., Indian Institute of Science, Bangalore; Charles Thompson, Associate Professor; B.S., New York University; M.S., Polytechnic Institute of New York; Ph.D., Massachusetts Institute of Technology; Anh Tran, Associate Professor; B.S., National Taiwan University; M.S., Ph.D., University of Rhode Island; David P. Wade, Associate Professor; B.S., Lowell Technological Institute; M.S., Northeastern University; Fahd G. Wakim, Associate Professor; B.S., American University of Beirut; M.A., Ph.D., University of Texas; Jay A. Weitzen, Associate Professor; B.S., M.S., Ph.D., University of Wisconsin, Madison; A. David Wunsch, Associate Professor; B.E.E., Cornell University; S.M., Ph.D., Harvard University.

Master of Science in Engineering Program

The Department of Electrical Engineering offers Master of Science in Engineering degrees in Electrical Engineering, Computer Engineering, and Systems Engineering. Students may pursue the Opto-Electronics Option in the master's programs in Electrical Engineering or Systems Engineering. Students may elect the thesis or non-thesis track; the thesis track is strongly encouraged. A master's degree will be awarded upon satisfactory completion of 30 credit hours of study in the thesis track, of which the thesis provides 6 credit-hours. Thirty-three credit hours of study are required in the non-thesis track, including the 3 credit hour seminar course 16.700, and 12 credit hours of study in a particular concentration.

B.S./M.S. Eng. Program

A five-year B.S./M.S. Eng. program is available in all three degree programs to undergraduates with a cumulative grade point average of at least 3.0 at the end of their junior year. See description in the front of this catalog.

Admission to the M.S. Eng. Programs in Electrical, Computer and Systems Engineering

Applicants must submit the application materials supplied by the Graduate School as well as the official score report for the Graduate Record Examination Aptitude Test. The TOEFL exam is required for students from abroad whose native language is not English.

M.S. Eng. Program in Electrical Engineering

Applicants to the M.S. Eng. program in Electrical Engineering should have received a B.S.E.E. or equivalent degree with an acceptable quality of undergraduate work from a recognized college or university. Students lacking the B.S.E.E. who hold a bachelor's degree in a physical science, mathematics, computer science, or engineering must have a knowledge of circuit theory, and must complete the following courses (and the prerequisites for these courses as required) at the University of Lowell, or equivalent courses at another recognized college or university where they are offered as part of a B.S.E.E. curriculum:

		credits
16.217	Minicomputer Operations and Programming	4
16.265	Logic Design	4
16.362	Signals and Systems	3
16.365	Electronics	3
16.311	Electronics Lab I	2
16.413	Linear Feedback Systems	3
16.461	Electromagnetic Theory II	3

M.S. Eng. Programs in Computer Engineering and Systems Engineering

To be eligible for admission to the master's degree programs in Computer Engineering and Systems Engineering, the applicant must have received a bachelor's degree or equivalent in a physical science, computer science, mathematics or an engineering discipline, from a recognized college or university, with an acceptable quality of undergraduate work.

The following undergraduate areas of study are prerequisites for the M.S. Eng. program in Computer Engineering:

	credits
Calculus	6
Advanced Mathematics	6
Circuit Theory, Electronics and associated laboratory	9
Combinational & Sequential Logic Design and laboratory	4-6
FORTRAN, Pascal, or C	3
Minicomputer Operations and Programming	3

Degree Requirements

Academic Advisor

Each graduate student admitted to graduate study in the Electrical Engineering Department will be assigned an academic advisor who will assist him or her in the selection of courses and who will develop with the student a program which will meet his or her requirements for the desired degree.

Master's Thesis Topics

Master's thesis research may be chosen in the following areas:

- Advanced computation
- Communications
- Electromagnetics and wave propagation
- Micro and minicomputer applications
- Microwave devices and circuits
- Electrooptics, optics, and optical information processing
- Power apparatus and systems
- Robotics and automation
- Semiconductors and devices
- Signal processing
- VLSI circuits and systems

Non-Thesis Track

A non-thesis student must elect a concentration to obtain a broader and deeper understanding of a particular area. A concentration requires the student to take four courses in a specific area, beyond the four required core courses.

Opto-Electronics Option

The Opto-Electronics Option is offered in cooperation with the Department of Physics, and may be pursued by students enrolled in the M. S. Eng. programs in Electrical Engineering or Systems Engineering. This option contains required and recommended courses designed to provide a fundamental background in optical devices and systems, as well as in optical physics and in the electro-optical properties of materials. A student may specialize in subjects that focus on one of three areas:

i) Application of optics in telecommunications and information processing
ii) Electrooptic phenomena and laser physics
iii) Fabrication and analysis of new electrooptic materials

Students electing this option are encouraged to pursue the thesis track. Active areas of research include optical information processing and computing at the component and system level.

M.S. Eng. in Electrical Engineering Requirements

Electrical Engineering Core Courses

16.509 Linear Systems Analysis
16.513 Modern Control Theory or
16.568 Electrooptic System Design (for enrollees in Opto-Electronics Option)
16.584 Probability and Random Processes
16.700 Seminar, or
16.743,6 MS Thesis

Electrical Engineering Concentrations

Computer Hardware
16.574 16.674 16.675 16.676
Computer Software
16.522 16.524 16.563 16.667
Control Systems
16.510 16.613 16.614 16.619
Electromagnetics
16.507 16.532 16.607 16.608
Information and Communications
16.543 16.545 16.548 16.685
Microwave Circuits and Systems
16.505 16.506 16.507 16.533
Opto-Electronics
16.503 80.539 80.547 80.551
Semiconductors and Microelectronics
16.502 16.503 16.504 16.603

M.S. Eng. in Computer Engineering Requirements

Computer Engineering Core Courses

16.520 Applied Numerical Methods, or
16.584 Probability and Random Processes
16.561 Computer Organization and Design
16.563 System Programming
16.574 Introductory Digital System Design
16.700 Seminar, or
16.743,6 MS Thesis

Computer Engineering Concentrations

Computer Architecture
16.522 16.664 16.671 16.674
Digital Design
16.502 16.674 16.675 16.676
System Software
16.522 16.524 16.663 16.667

M.S. Eng. in Systems Engineering Requirements

Systems Engineering Core Courses

16.509 Linear Systems Analysis
16.513 Modern Control Theory or
16.568 Electrooptic System Design (for enrollees in Opto-Electronics Option)
16.584 Probability and Random Variables
16.700 Seminar, or
16.743,6 MS Thesis

Systems Engineering Concentration

Because of the wide range of topical coverage in Systems Engineering and the interdisciplinary nature of the Systems Engineering

program, a non-thesis Systems Engineering student may follow one of the Electrical Engineering concentrations listed above, or may design a special concentration meeting his or her specific academic objectives, with advice and consent of the M.S. Eng. program coordinator. Master of Science in Eng. students in Systems Engineering pursuing the Opto-Electronics Option will complete 16.503, 80.539, 80.547, and 80.551.

Doctor of Engineering Program

Objective

The goal of the Doctor of Engineering Program is to develop decision-making, research-oriented engineers with ability to produce new engineering knowledge. The program includes advanced graduate coursework in electrical engineering and allied subjects, a sequence of specialized courses in engineering management, and research culminating in a doctoral dissertation. The Doctor of Engineering degree requires completion of 89 semester hours of academic credit beyond the bachelor's degree. A typical program consists of the following:

Engineering Subject Courses	40 credits
Internship & Dissertation	30 credits
Engineering Management	15 credits

The Engineering Management program is administered at the college level and is described under the heading: College of Engineering, Doctor of Engineering Program, under the College of Management.

Admission Requirements

Applicants must have a B.S. or M.S. degree in Electrical Engineering or its equivalent from a recognized college or university with an acceptable quality of prior academic work. Applicants must submit the admissions materials supplied by the Graduate School Office and official transcripts of all prior undergraduate and graduate courses. Each applicant must submit an official score report of the Graduate Record Examination Aptitude Test. The TOEFL exam is required for students from abroad whose native language is not English.

Transfer Credit

Up to 24 credits in graduate engineering courses are transferrable to the doctoral program upon approval by the Department's Doctor of Engineering Committee.

Internship and Dissertation

Each student is required to complete an internship of at least one year's duration in industry, government, or the University. The purpose of the internship is to place the student in a realistic engineering setting in which he or she will function as a responsible engineer and carry out the work required for the dissertation. During the internship, the student will maintain close contact with the academic advisor. A written dissertation must be submitted and defended orally.

Language Requirements

The student must demonstrate satisfactory reading ability (level two) in one foreign language (German, Russian, French or Spanish) which is not the student's native tongue. The language requirement may be satisfied by:

a) Passing an examination given by the Graduate Committee of the Electrical Engineering Department, or
b) Completing a one-year course beyond the first year with a grade of B or better.

Other Requirements

One year of full-time residency is required of all students in the program. To successfully complete the program, a student must achieve a cumulative grade point average of 3.25 in all course work.

Plan of Study

Each student entering the program must develop a program plan of study in consultation with his/her Advisory Committee. During the first year, the student will take 24 credit hours of engineering courses and take or prepare for the qualifying exam. During the second year, the student will continue the required course work and will formulate a topic for the dissertation. The final period will be devoted to advanced courses and to dissertation work.

Qualifying Examination

A complete description of the doctoral qualifying examination may be found in the Electrical Engineering Department's Doctoral Student Handbook.

The qualifying examination consists of Part A and Part B. Part A is at the undergraduate level and is taken early in the program. Students who are not yet in the doctoral program but are interested in applying for admission may take Part A provided they meet certain requirements. Part B is at a more advanced level and tests the student in his/her chosen area of concentration and allied subjects.

Dissertation Proposal

Having passed the qualifying examination, the student may submit his or her dissertation proposal and defend the proposal before the Doctoral Committee. Upon approval, the student's name will be submitted to the College Doctoral Committee and the Dean of the Graduate School for acceptance as a Candidate for the Doctor of Engineering Degree. Admission to candidacy status does not guarantee the obtaining of the degree.

Course Requirements

Core Doctoral Courses

The following courses are required for all students in the Electrical Engineering doctoral program:

16.507	Electromagnetics
16.509	Linear Systems Analysis
16.584	Probability and Random Processes
16.574	Introduction to Digital System Design
16.520	Applied Numerical Methods,
	or
92.523	Linear Algebra,
	or
95.513	Classical Mechanics

Concentration

After passing the qualifying exam, the student will select one of the five available concentrations of the doctoral program: Computers, Electromagnetics, Power, Semiconductors and Microelectronics, or Systems. Recommended courses in these concentrations are listed below. Each required course within an option is marked with an "R".

Computers Concentration

16.520	Applied Numerical Methods	R
16.522	Data Structures	
16.524	Programming Languages	
16.525	Simulation Techniques	
16.543	Introduction to Communication Theory	
16.545	Coding Theory	
16.548	Information Theory	
16.561	Computer Organization and Design	
16.563	System Programming	R
16.661	Computer & Local Area Networking	
16.662	Microprogramming	
16.663	Compiler Structures	
16.664	Parallel Processing	
16.667	Operating Systems	
16.671	Advanced Computer Architecture	
16.674	Digital Subsystem Design	
16.675	Advanced Digital Devices	
16.676	Digital System Design Laboratory	
16.685	Statistical Communication Theory	

Electromagnetics Concentration

16.505	Microwave Electronics	
16.506	Antenna Theory and Design	
16.520	Applied Numerical Methods	
16.532	Computational Electromagnetics	R
16.533	Microwave Engineering	

16.534	Microwave Laboratory	
16.571	Radar Systems	
16.582	RF Communication System Design	
16.583	Wave Propagation in Plasmas	
95.505	Mathematical Physics I	
95.506	Mathematical Physics II	
16.607	Electromagnetics II	R
16.608	Scattering and Diffraction of EM Waves	
16.609	Inverse Scattering and Source Theory	

Power Concentration

16.515	Power Electronics	R
16.516	Advanced Machine Theory	R
16.520	Applied Numerical Methods	
16.615	Solid State Drive Systems	
16.616	Computational Power Systems Analysis	
16.619	Digital Control Systems	
16.674	Digital Subsystem Design	
16.675	Advanced Digital Devices	
16.676	Digital System Design Lab	
24.527	Solar Energy Engineering	
92.523	Linear Algebra	

Semiconductors and Microelectronics Concentration

16.502	Introduction to VLSI Design	R
16.503	Solid State Physical Electronics I	R
16.504	VLSI Fabrication	R
16.505	Microwave Electronics	
16.535	Microsensors	
16.602	Advanced VLSI Design	
16.603	Solid State Physical Electronics II	
16.605	Selected Topics in Semiconductors	

Systems Concentration

16.520	Applied Numerical Methods	R
16.521	Robotics	
16.525	Simulation Techniques	
16.543	Introduction to Communication Theory	
16.545	Coding Theory	
16.613	Nonlinear Systems Analysis	
16.614	Optimal Control Theory	
16.619	Digital Control Systems	
16.676	Digital System Design Laboratory	
16.685	Statistical Communication Theory	R
16.686	Random Processes	
16.687	Stochastic Estimation Theory & Applications	

Further details regarding the doctoral program are listed in the Department of Electrical Engineering *Doctoral Student Handbook*, which is up-dated annually.

Course Descriptions

16.502 Introduction to VLSI Design (2-3)3
Prerequisite: 16.265 and 16.365
MOS devices; NMOS and CMOS circuit forms and methodologies. Logic design techniques and circuit architectures. Logic and circuit specification, design, layout, and verification. Logic-level, switch-level, and SPICE circuit simulation. Laboratory exercises and project.

16.503 Solid State Physical Electronics I (3-0)3
Prerequisite: 16.360 I
Introduction to the behavior of solid state materials. Planck's quantization hypothesis, Bohr's model of the atom, wave-particle duality, wave packets and Schroedinger's equation. Crytalline and amorphous materials. Band theory of solids; electrons and holes. Metals, insulators and semiconductors. Semiconductor behavior.

16.504 VLSI Fabrication (3-0)3
Prerequisite: 16.365
Fabrication in EE Dept. labs of resistors, capacitors, pn junctions and Schottky barrier diodes, BJTs, MOS devices, and ICs. Introduction to silicon structures, wafer preparation, testing, and packaging. Mathematical models for diffusion, oxidation, ion implantation, image creation, etching, photolithography and microcircuit processing.

16.505 Microwave Electronics (3-0)3
Prerequisites: 16.365, 16.461
Review of EM theory and PN junctions. Varactors and step-recovery diode multipliers. Microwave transistors. Tunnel diodes. FETs. Transferred electron devices - the Gunn diode. Avalanche diodes - IMPATT, TRAPATT AND BARITT diodes. Quantum electronic solid state sources - ruby masers and semiconductor lasers. Parametric and IR devices.

16.506 Antenna Theory and Design (3-0)3
Prerequisite: 16.461
Introduction of the fundamental principles of antenna theory; analysis, synthesis and design. Antenna parameters. Electromagnetic fields due to prescribed sources; near and far regions; reciprocity. Infinitesimal dipole. Arrays (patterns, mutual coupling). Array synthesis. Dipole, linear wire, loop, traveling wave, frequency independent, aperture, and horn antennas.

16.507 Electromagnetics I (3-0)3
Prerequisite: 16.461
Maxwell's equations. Electric and magnetic potentials. Boundary conditions. Solution of scalar and vector Laplace equation in one, two and three dimensions. Multipole expansion of potentials. Solution of scalar Helmholtz equation. Applications to wave propagation in bounded media.

16.509 Linear Systems Analysis (3-0)3
Prerequisite: 16.362
Fourier series and Fourier transforms (FT): convergence properties; applications to linear systems including modulation, sampling and filtering. Hilbert transforms (HT). Bilateral Laplace transforms (LT): convergence properties. Contour integration methods applied to FT, HT and LT. Discrete-time Fourier series and Fourier transforms: applications to linear systems. Discrete Fourier transforms and Fast Fourier algorithm. Z-transforms: convergence properties, solution of difference equations, application to linear systems. Correlation.

16.510 Digital Signal Processing (3-0)3
Prerequisites: 16.362, 16.509 Definition of discrete signals and systems. Difference equations. Representation of linear shift-invariant discrete systems. z-transform. Discrete Fourier transform and series. Digital filtering and digital filter design. Computation of the discrete Fourier transform. Discrete random signals.

16.513 Modern Control Theory (3-0)3
Prerequisites: 16.413
The state-space, linear algebraic approach to linear time-invariant and time varying systems. Controllability and observability. Time domain design of feedback control systems; continuous time and discrete time systems.

16.515 Power Electronics (3-0)3
Prerequisites: 16.355 & 16.366
Design and performance analysis of rectifiers, inverters, DC choppers, AC voltage controllers, cycloconverters, and power supplies. The course includes a design project in the laboratory.

16.516 Advanced Machine Theory (3-0)3
Prerequisite: 16.355
Electromechanical energy conversion. Reference-frame theory. Dynamics of DC, induction, and synchronous machines. Unbalanced operation of induction and synchronous machines.

16.520 Applied Numerical Methods (3-0)3
Prerequisite: 92.234
Taylor series. Number systems and error. Gaussian method of linear algebra. Matrix eigenvalues. Difference and summation calculus. Interpolation. Definite integrals. Differential equation modeling and stability; Predictor-Corrector and Runge-Kutta methods. Orthogonal polynomials.

16.521 Robotics (2-2)3
Prerequisite: 16.362
Movement and imaging under the homogeneous representation. Robotic joints. Classification and analysis of robots; inverse kinematic solutions. Parametric description of curves. Trajectory planning, dynamics and control.

16.522 Data Structures (3-0)3
Prerequisites: FORTRAN and Pascal or instructor's permission.
Character strings, character substring searches; lists, their storage structure and uses; trees, tree searches, and storage concepts; compiling; Polish strings; translating from infix to postfix and prefix; conversion to machine code.

16.524 Programming Languages (3-0)3
Prerequisite: FORTRAN or Pascal Syntax and semantics of programming languages.
Fundamental concepts of control structures, modularity, scope of identifiers, recursion, and data structures. Examples of real programming languages such as FORTRAN-77, Pascal, LISP, APL, C and ADA.

16.525 Simulation Techniques (3-0)3
Prerequisites: FORTRAN, 16.366
A study of modern techniques for the simulation of continuous and discrete time systems and processes. Model building, simulation organization, statistical consideration and model validation will be discussed. Discrete and integrated semiconductor models. Study of a number of physical

and engineering systems by use of simulation techniques on available computers.

16.531 Active Network Synthesis (3-0)3
Prerequisite: 16.366
Controlled sources. Impedance converters and inverters. Synthesis techniques using the negative impedance converter, the gyrator, and the operational amplifier. Active filter theory. Transcendental systems. Continued fraction expansions. Canonic realizations.

16.532 Computational Electromagnetics (3-0)3
Prerequisite: 16.461
Formulation of electromagnetic problems for computer solution. Variational principles in electromagnetics. Method of moments. Applications in electrostatics, wire antennas, waveguides and cavities. Simple scattering problems. Finite difference methods. Finite element method.

16.533 Microwave Engineering (3-0)3
Prerequisite: 16.461
TEM and quasi-TEM transmission lines. Strip, microstrip, slot and coplanar lines. Rectangular and circular waveguides. Dielectric image line. Microwave circuit theory. Z, Y, scattering and ABCD parameters. Passive components. Ferrites. Microwave measurement techniques.

16.534 Microwave Laboratory (2-3)3
Prerequisite: 16.403 or 16.533.
Measurement of frequency and wavelength, standing wave ratio and shift in minima. Measurement of dielectric constant for lossless and lossy dielectrics, power, return loss, and S-parameters of a junction. Measurement of input impedance of an antenna over a ground plane.

16.535 Microsensors (3-0)3
Prerequisite: 16.366
Microsensors in measurement and control systems. Characteristics of sensors; analysis of transfer characteristics; theory of accuracy and conversion; dynamic characteristics. Concepts of solid state structures; fabrication of microelements. Merging, interfacing, and integrating with signal conditioner; partitioning in signal conditioning. Alternatives to microsensors.

16.543 Introduction to Communication Theory (3-0)3
Prerequisite: 16.362, 16.471
Signal and linear systems analysis; Fourier series and transforms; energy and power correlation functions and spectral densities; sampling and modulation; Hilbert transforms in communications. Amplitude, frequency and various pulse modulation techniques; spectral analysis; analysis of phase-locked loops. Random signals and noise; statistical properties of noise and its effect on AM, FM and pulse modulation systems. Introduction to digital data transmission.

16.545 Coding Theory (3-0)3
Concepts and recent developments in the use of codes for error control in data handling systems. Encoding and decoding procedures and their implementation in computational algorithms and hardware organizations are investigated in detail.

16.548 Information Theory (3-0)3
Prerequisite: 16.471
Probabilistic measure of information. Determination of the information handling capacity of communication channels and fundamental coding theorems. Introduction to information coding and error correcting codes.

16.561 Computer Organization and Design (3-0)3
Prerequisites: 16.217 and 16.265
Introduction to computer organization and architecture analysis with application to single processor digital systems. Instruction and data formats; computer arithmetic. Models of computing and complexity tradeoffs. Instruction set and register transfer level architectures and design methodology. Data cache and virtual memory concepts.

16.563 System Programming (3-0)3
Prerequisite: 16.217
System programming structures with emphasis on re-entrant programming and pure procedures. Nested calls, push-down stacks and queues. Re-entrant interrupt programming, activation records and program sharing. Memory allocation by absolute and relocatable loaders. Macro languages, processes and assemblers.

16.568 Electrooptic System Design (3-0)3
Prerequisite: 16.360
Geometric and Fourier optics, coherence, fiber optics, resonators, interaction of radiation with matter, laser theory and design, radiation detection, nonlinear optics and light modulation. Experimental project.

16.571 Radar Systems (3-0)3
Prerequisite: 16.461
Introduction to both pulsed and CW radar systems. Detection of radar echoes in noise. The radar equation and its use in estimating performance of a radar system. Estimation of range, direction and velocity of targets. Moving target indicators. Pulse compression and other advanced techniques. Discussion of elements of practical radar systems.

16.574 Introduction to Digital System Design (3-0)3
Prerequisites: 16,217, 16.265 and 16.365
Formal representation and manipulation of switching functions including n-cubes and Reed-Muller canonical form. Synthesis procedures for combinational and sequential circuits including Quine-McCluskey minimization and finite state machine inversion. Design of complex register level functions using Programmable Logic Devices and gate arrays.

16.582 RF Communication System Design (3-0)3
Prerequisite: 16.461
Study of radio wave propagation. Factors affecting the performance of terrestrial line-of-sight microwave radio systems and cellular mobile radio systems. Design and field operation of QAM digital radio systems. Computation of statistics of system performance including availability and errors.

16.583 Wave Propagation in Plasmas (3-0)3
Prerequisite: 16.461
Plasma waves and the interaction of electromagnetic radiation with plasmas, specifically the earth's ionosphere. Refraction, reflection, dispersion, absorption, and ray paths. Ionospheric effects on ground-to-ground and ground-to-satellite radio and over-the-horizon radar systems. Review of ionospheric physics.

16.584 Probability and Random Processes (3-0)3
Co-requisite: 16.509; Prerequisite: 16.362
Axiomatic definition of probability. Bayes' theorem. Repeated trials. Continuous and discrete random variables and their probability distribution and density functions: expectation, variance and moments. Characteristic and generating functions. Mean square estimation. Introduction to random processes: distribution and density functions; time and ensemble averages; correlation functions and spectral densities; applications to linear systems. Recursive filtering: discrete and continuous Kalman filter.

16.602 Advanced VLSI Design (3-0)3
Prerequisite: 16.502
Logic abstraction, digital circuit optimization techniques, clocks and communication design of array structures. The microarchitecture of VLSI systems. SPICE models for regenerative logic circuits and memories. Laboratory exercises and project leading to chip fabrication.

16.603 Solid-State Physical Electronics II (3-0)3
Prerequisite: 16.503
Semiconductor devices: Schottky diodes, PN junction devices, bipolar junction transistors, field effect transistors, photodiodes, varactors. Electro-optic devices, thermoelectric devices, electroluminescent diodes and laser diodes. Heterostructures and quantum well devices.

16.605 Selected Topics in Semiconductors (3-0)3
Prerequisite: 16.503.
Advanced topics in the fabrication, analysis, and simulation of semiconductor materials and devices.

16.607 Electromagnetics II (3-0)3
Prerequisite: 16.507
Plane wave representation of electromagnetic waves. Angular spectrum of plane waves for two and three dimensions. Green's function method of solution for self adjoint boundary value problems. EM wave propagation in stratified media. Dyadic Green's function and applications.

16.608 Scattering and Diffraction of EM Waves (3-0)3
Prerequisite: 16.507
Review of EM Theory. Scattering from a long cylinder for TM and TE waves. Scattering pattern and cross section. Scattering from a sphere. Rayleigh and Mie regions. Half-plane and wedge diffraction. GTD and applications for high frequency scattering. Babinet's principle and diffraction by an aperture. Physical theory of diffraction. Weiner-Hopf methods.

16.609 Inverse Scattering and Source Theory (3-0)3
Prerequisite: 16.507
Inverse scattering theory and diffraction tomography: the Born and Rytov approximations. Characterization of scatterer from the scattered wave and "exact" inversion methods. Inverse source

theory; synthesis of sources to give prescribed radiating waves and signals.

16.613 Nonlinear Systems Analysis (3-0)3
Prerequisite: 16.520
Roots of polynomials. Zeros and stationary points of single variable functions. Gradient, Quasi-Newton and conjugate gradient methods of constrained optimization. Approximation methods for ordinary and partial non-linear differential equations. Stability and the methods of Lyapunov.

16.614 Optimal Control Theory (3-0)3
Prerequisites: 16.509 and 16.513
Deterministic optimal control systems. Performance measures for optimal systems. Dynamic programming and related computer techniques. Discrete linear regulator. The Hamilton-Jacobi-Bellman equation. Continuous linear regulator. Calculus of variations and Pontryagin's minimum principle. Minimum time problems. Minimum effort problems.

16.615 Solid State Drive Systems (3-0)3
Prerequisite: 16.515
Elements of variable speed drive systems. Rectifier and chopper control of DC drives. Control of induction motors by AC voltage controllers. Frequency-controlled induction motor drives. Slip-power controlled wound-rotor induction motor drives. Synchronous motor speed control.

16.616 Computational Power System Analysis (3-0)3
Prerequisites: 16.443 and 16.520
Power system matrices, power flow studies, fault studies, state estimation, optimal power dispatch, and stability studies.

16.619 Digital Control Systems (3-0)3
Prerequisites: 16.510 and 16.513
Discrete-time systems. Sampling and reconstruction of signals. Z-transform. Output and state feedback. Stability. Pole assignment and design of digital controllers. State estimation. Introduction to Kalman filters.

16.661 Computer & Local Area Networking (3-0)3
Prerequisites: 16.561 and 16.563
Characteristics and topology of Local Area Networks (LANs). Access control protocols. Standards. Design of cable plants. Digital data switch. Voice/data computerized CBX. Device/LAN interface. Performance and evaluation of LANs and computer networking.

16.662 Microprogramming (previously 16.562) (3-0)3
Prerequisites: 16.561 and 16.574
Horizontal and vertical microprogramming structures including finite state machine controllers. Implementation of digital functions as firmware on microprocessors. Register transfer assemblers. State partitioning and optimization. Micro-instruction set design and design of microprogrammed data paths.

16.663 Compiler Structures (3-0)3
Prerequisite: Pascal, 16.563
Translators and interpreters for programming languages. Syntax of programming languages, syntax directed compilation. Parsing techniques: operator precedence, top down, bottom up and reductive strategies. Generation and optimization of machine code. Error handling: detection and correction. The run time environment, storage allocation.

16.664 Parallel Processing (3-0)3
Prerequisites: 16.563 and 16.561
Supercomputer organization, architectures and application algorithms. Multiple pipeline, bus, and switch based multiple processor systems. Multi-level cache and multi-dimensional access memory structures. Neural network models and implementations. Current research and production parallel processing computers.

16.667 Operating Systems (previously 16.564) (3-0)3
Prerequisite: 16.563
Scheduling and communication of the resources of large computer systems. Sequential and concurrent processes allowing program sharing, multi-programming, multi-processing, memory sharing and protection. Paging, segmentation and swapping strategies. Time sharing and multiple-task operating systems. Design and simulation of operating system behavior.

16.671 Advanced Computer Architecture (3-0)3
Prerequisite: 16.561
Architectural analysis of high performance single processor and systolic processor systems. Memory structure optimization, pipeline control and high-speed arithmetic structures. Cost and performance of switch-based multiple processor systems. Analysis of alternative architectures including associative array and data flow machines.

16.674 Digital Subsystem Design (3-0)3
Prerequisite: 16.574
Algorithms at the register transfer level; cost and performance tradeoffs with decomposition and optimization. Design of complex digital structures using large scale integrated and semi-custom devices. Detailed timing analysis of processor interface busses and memory subsystems. Use of special purpose microprocessors to realize digital systems.

16.675 Advanced Digital Devices (3-0)3
Prerequisite: 16.674
State-of-the-art microprocessors are examined and compared. The four architectural concepts of memory segmentation, operated addressing structure, operation register set, and instruction encoding scheme are evaluated for different families of processor design. Arithmetic and logical instruction support for high performance numeric processing.

16.676 Digital System Design Laboratory (2-3)3
Prerequisite: 16.674
Brief introduction to C. Application of digital devices and systems to realistic engineering problems. Design, development, construction, and testing of systems emphasizing state-of-the-art digital design methodologies. Enrollment limited; extensive time in laboratory required.

16.685 Statistical Communication Theory (3-0)3
Prerequisites: 16.509, 16.584
Review of probability and random variables. Random processes; statistics of white noise; Fourier analysis of periodic random processes; Karhunen-Loeve expansion; narrow-band Gaussian processes; linear systems. Discrete-time and continuous-time matched filters; spectral factorization and solution of integral equations. Maximum likelihood receivers. Digital modulation. Information theory: entropy, ratio distortion theory, channel capacity, and introduction to coding.

16.686 Random Processes (3-0)3
Prerequisite: 16.584
Review of probability and random variables; fields and measure. Definition of a random process and its convergence aspects. Bernoulli, Poisson, and Markov processes. Brownian motion. Markov chains and diffusion processes. Kolmogorov backward and forward equations. Stochastic integrals and differential equations. Stochastic calculus. Statistical filtering and estimation.

16.687 Stochastic Estimation Theory & Applications (3-0)3
Prerequisite: 16.584
A review of random vectors. Estimation theory for dynamic systems based on the orthogonality principle, Bayesian and maximum likelihood methods. Discrete-time and continuous-time Kalman filter; applications to communication and navigation systems. Smoothing of discrete-time signals. Parameter identification and adaptive estimation.

16.700 Seminar (3-0)3
Prerequisites: Minimum of 15 credit-hours of graduate courses; for students in the non-thesis option only.
Development, preparation, and written and oral presentation of a report on an advanced engineering topic: Oral presentation of proposals; modification and redefinition as required; oral presentation to the class and instructor of results of investigation; submission of final written report. Grade based on clarity of exposition, knowledge of subject, ability to clearly and effectively answer questions, and participation in the discussion of other papers. Class size limited to ten students.

16.710-729 Selected Topics in Electrical Engineering (3-0)3
Prerequisites: Specified at time of offering.
Advanced topics in various areas of electrical engineering and related fields.

16.740 Advanced Project (0-6)3
The Advanced Project is a substantial investigation of a research topic under the supervision of a faculty member. A written proposal must be on file in the Electrical Engineering Graduate Office before enrollment. A written report is required upon completion of the project. This course can be taken only once, and may evolve into a master's thesis. However, credit for this course will not be given if thesis credit is received.

16.743 Master's Thesis Research (0-6)3

16.746 Master's Thesis Research (0-12)6
Co-requisites: Minimum of 6 credit-hours of graduate courses at an acceptable level when registering for first three credits and 12 credit hours when registering for subsequent credits; approval of a written proposal outlining the extent and nature of proposed research work.
The report on the research work, performed under the supervision of a faculty member, must be published in appropriate form and presented to a committee of three faculty members appointed

at the time of acceptance of the thesis proposal. The student is required to give an oral defense of the thesis before the committee and other faculty members. The committee may recommend to the Graduate Affairs Committee that more than 6 credit-hours be granted for work of an exceptional nature.

16.753 Doctoral Dissertation Research (0-6)3

16.756 Doctoral Dissertation Research (0-12)6

16.759 Doctoral Dissertation Research (0-18)9
Prerequisites: Written approval by the dissertation advisor. No more than 9 credits of doctoral dissertation research may be taken before passing the doctoral qualifying examination. No more than 15 credits of doctoral dissertation research may be taken before passing the defense of thesis proposal examination.

Department of Work Environment

Department Chairperson: David H. Wegman, Professor; B.A., Swarthmore College, M.S. Harvard School of Public Health, M.D. Harvard Medical School.
Graduate Coordinator: Michael J. Ellenbecker, Professor; B.E.E. University of Minnesota, M.S. University of Wisconsin, M.S., Sc.D. Harvard School of Public Health.
Faculty: Ellen A. Eisen, Associate Professor; B.S., University of Michigan, M.S., Massachusetts Institute of Technology, M.S., Sc.D., Harvard School of Public Health. Kenneth R. Geiser, Jr., Associate Professor; B.Arch., University of California, Berkeley, M.C.P., Ph.D., Massachusetts Institute of Technology. David Kriebel, Assistant Professor; B.S. University of Wisconsin (Green Bay), M.S., Sc.D., Harvard School of Public Health. Charles Levenstein, Professor; B.S.. Cornell University, Ph.D.,Massachusetts Institute of Technology, M.S.O.H., Harvard School of Public Health. Rafael Moure-Eraso, Associate Professor; B.Ch.E., University of Pittsburgh, M.Ch.E., Bucknell University, M.S., Ph.D., University of Cincinnati. Laura Punnett, Assistant Professor; B.A., Hampshire College, M.S., Sc.D., Harvard School of Public Health.

Graduate Programs in Work Environment

The graduate programs are designed to prepare practitioners and research scientists with advanced knowledge in: 1) identification and measurement of exposures to chemical and physical hazards in work environments, 2) design and evaluation of control strategies for these types of exposures, 3) investigation of risk factors for work-related disease and the effectiveness of control or prevention strategies, and 4) development and analysis of strategies for the reduction of disease risk in the work environment based on public and private policy alternatives.

Master of Science

The Master of Science program will prepare graduates with the master's degree in one of four work environment disciplines (industrial hygiene, occupational ergonomics, occupational epidemiology and work environment policy). The Department offers a program leading to the master's degree with thesis or non-thesis options. Candidates choosing the thesis option are guided by a committee of three faculty members.

Doctor of Science

The doctoral program is designed to prepare research scientists with the ability to bring advanced research capabilities to the identification and control of work related health risks. The program includes advanced graduate work in each of the four work environment concentrations (industrial hygiene, occupational ergonomics, occupational epidemiology and work environment policy). Candidates will, under the direction of a faculty advisor and dissertation committee, carry out original research culminating in a doctoral dissertation.

Master of Science Degree Program

Admission Requirements

Successful applicants will meet the standards of the Graduate School of the University of Lowell and, in addition, will have demonstrated the ability and motivation necessary for independent creative work and an interest in issues of the work environment. Strong preference will be given to candidates with both a quantitative academic background and experience in industry, government or health care. At the same time, the faculty of the Department of Work Environment believes that the program (and the profession) is strengthened by admitting students from a wide diversity of backgrounds, and therefore students with "non- traditional" educational or work backgrounds will be considered carefully.

To be successful, an applicant to the Master of Science degree program in Work Environment will need to have a baccalaureate degree or its equivalent from an accredited institution. The applicant must show an acceptable grade point average (3.0) and demonstrate preparation in quantitative sciences. It is expected that the great majority of applicants will provide evidence of completing at least a year of physics, calculus and organic chemistry at the college level. Preference will be given to applicants with such preparation. No applicant will be accepted without evidence of strong preparation in mathematics, and a semester in statistics is strongly recommended for all concentrations. Applicants intending to study ergonomics must provide a record of adequate performance in college physics. Applicants intending to study industrial hygiene must provide a record of adequate performance in college physics and organic chemistry. The G.R.E. Aptitude Test is required for all applicants unless they already hold a graduate degree and the Graduate Coordinator requests that the Graduate School waive the requirement.

Academic Advisor

Each graduate student admitted into the Department of Work Environment will be assigned an academic advisor who will assist in the selection of courses and who will develop, with the student, a program which will meet the needs and requirements for the desired concentration. For a master's degree candidate who selects the non-thesis option, the academic advisor will supervise the advanced research project.

Master's Thesis

A student selecting the thesis option will arrange, through the academic advisor, to have a three member faculty committee appointed at the time a thesis proposal is submitted. The committee is responsible for approval of the proposal. The report on the research work will then be performed primarily under the supervision of the academic advisor. The thesis must be prepared in appropriate form and be presented to the thesis committee for final approval. The student is required to give an oral defense of the thesis before the committee and other faculty members.

Course Requirements for the Master's Degree

A core of 23 credits is required of all students in the master's degree program. An additional 25 credits is required for each of the concentrations for students with no prior experience. Requests for waiver of any specific course requirements will be considered on a case by case basis and will depend on documentation of equivalent course work at another institution.

Core Courses:

19.503	Health Effects of Occupational Exposures	3
19.513	Health Hazards of Manufacturing Processes	3
19.551	Work Environment Policy I	3
19.570	Introduction to Occupational Epidemiology	3
19.570	(701) Epidemiology Lab	1
19.581	Biostatistical Methods for the Work Environment	3
19.599	Work Environment Seminar	1

19.690	Critical Review of the Scientific Basis of Occupational Health Standards	3

Areas of Concentration

Occupational Ergonomics: Ergonomics provides the scientific basis for optimized design of the work environment compatible with the capabilities and limitations of the working population. An ergonomist is trained to recognize, evaluate, and control hazards in the work environment that result from a poor fit between the worker and the workplace; these hazards may result in acute injury, chronic musculoskeletal disorders, or mental/psychosocial "stress." The physical demands of machines, tools, and work methods must accommodate the range in size, strength, mobility, dexterity, and endurance of the workforce. The information flow between the equipment and the worker must be structured so that the worker can process and respond appropriately without being mentally overstressed to the degree that errors result.

The concentration in Ergonomics is designed to develop an understanding of human anatomy, physiology, and psychology, of industrial hygiene and epidemiology as well as modern manufacturing technology and work organization.

It provides a multidisciplinary background in these basic areas, as well as their application to the practical problems in ergonomics that are encountered in industrial and service work environments.

The following courses are required in addition to the core:

19.510	Intro. to Industrial Hygiene	3
19.511	Industrial Hygiene Sampling Lab	1
19.512	Exposure Assessment	3
19.530	Ergonomics and Work	3
19.531	Occupational Biomechanics	3
19.531	(.801) Occup Biomech. Lab	1
19.517	Physical Agents: Evaluation & Control	2
19.540	Design for Injury Prevention	3
	OR	
19.542	Human Factors	3
19.558	Occupational Health Administration I	3
19.746	Ergonomics Thesis	6
	OR	
19.723	Research Project in Ergonomics and Elective	6

Industrial Hygiene: Industrial hygiene is concerned with the protection of worker health through the prevention of occupational illness. Industrial hygienists accomplish this goal through the recognition, evaluation, and control of chemical and physical hazards in the work environment. The control of such hazards allows the worker to perform his/her job in a productive manner, free from the debilitating effects of work-related illnesses.

Graduates will be prepared in the initial diagnosis of exposure problems in industrial settings, in the development of a sampling and evaluation strategy to characterize the extent of the problem, in the proper field collection and laboratory techniques to measure environmental exposures, in the determination of the environmental controls needed to solve the identified exposure problems, and in the theoretical and practical design aspects of such controls.

The following courses are required in addition to the core:

19.512	Exposure Assessment	3
19.514	Aerosol Science	3
19.515	Measurement of Airborne Contaminants	3
19.517	Physical Agents Evaluation & Control	2
19.518	Industrial Ventilation	2
19.530	Ergonomics and Work	3
	OR	
19.540	Design for Injury Prevention	3
	OR	
19.542	Human Factors	3
19.550	Environmental Law and Policy	3
19.558	Occupational Health Administration I	3
19.746	Industrial Hygiene Thesis	6
	OR	
19.721	Research Project in Industrial Hygiene and Electives	6

Epidemiology: Epidemiology is the study of the distribution and determinants of disease in human populations. Today's occupational epidemiologist is called upon to identify previously unsuspected diseases caused by exposure to hazards in the work environment, to assess the health risks of new technologies, to recommend a scientific basis for the setting of occupational standards to protect worker health, and to evaluate the ability of control technologies to limit health risks. Epidemiology is a rapidly evolving discipline using increasingly sophisticated statistical methods to quantify the risks of low level, long term exposures to hazardous physical and chemical agents. The field is highly interdisciplinary, drawing on physiology, toxicology, biostatistics, industrial hygiene and biomechanics.

To meet the need for epidemiologists in industry, government and academia, the student in the epidemiology concentration will be trained in the full spectrum of epidemiologic methods, and will acquire the necessary background in the related fields of biostatistics, physiology, industrial hygiene, and ergonomics.

The following courses are required in addition to the core:

19.510	Intro. to Industrial Hygiene	3
19.511	Industrial Hygiene Sampling Lab. I	3
19.512	Exposure Assessment	3
19.550	Environmental Law and Policy	3
19.571	Epidemiology Methods II	3
19.572	Occupational Epidemiology II	3
19.674	Multivariate Methods in Epidemiology	3
19.—	Upper Level Elective in Epi or Biostsat	3
19.746	Occup Epidemiology Thesis and Elective	6
	OR	
19.727	Research Project in Occup Epidemiology and Elective	6

Work Environment Policy: The policy analyst must understand the interaction between science (and scientific uncertainty) in occupational health and the politics of the workplace setting. Occupational health as a field is integrated by the practical focus on actual workplace conditions: policy is based on the science; engineering and political economy provide the solutions.

The Work Environment Policy concentration will provide master's level education to graduates from a wide variety of backgrounds, including the social sciences and law, who wish to be administrators of occupational health and safety programs in the private and/or public sectors, or who wish to be policy analysts in agencies and organizations concerned with affecting worker safety and health.

The following courses are required in addition to the core:

19.510	Intro. to Industrial Hygiene	3
19.511	Industrial Hygiene Sampling Lab.	3
19.550	Environmental Law & Policy	3
19.552	Work Environment Policy II	3
19.558	Occupational Health Administration I	3
19.561	Occupational Health Administration II	3
19.683	Risk Assessment in Workplace & Environment	3
19.746	Work Env. Policy Thesis	6
	OR	
19.725	Research Project in Work Env. Policy and Elective	6

Doctor of Science Degree Program

Admission Requirements

Doctoral training is built upon the substantial didactic training gained in the master's degree programs. To be eligible for admis-

sion to a doctoral program, an applicant will need to demonstrate appropriate undergraduate education with adequate preparation in quantitative sciences. For an applicant who has not obtained a master's degree in work environment or a related field, direct admission to the doctoral program will be possible but will require documentation that the equivalent course work has been completed. He or she will need to provide a minimum of three letters of reference attesting to the ability to perform advanced graduate work and to provide a written statement of career objectives and the relationship of doctoral training to those objectives. Evidence of academic ability must be provided in the form of undergraduate and graduate transcripts detailing an acceptable grade point average (generally a minimum of 3.0 with 3.5 in quantitative sciences). Performance on the Graduate Record Examination Aptitude Test must be at a high level. An applicant who already holds a graduate degree may request waiver of the G.R.E. requirement. Finally, a personal interview will be required in selected cases.

For a doctoral candidate, the primary responsibility for evaluating progress will rest with the student's academic advisor along with the Dissertation Committee. Upon matriculation, the student will be assigned a provisional advisor. Within one semester after completing the core courses, the student must select a final advisor and identify a research topic. The advisor will assist the student in complying with all the university requirements in achieving eligibility for the degree.

Doctoral Dissertation

The doctoral dissertation will be based on a substantial body of original research carried out by the candidate. The selection of the research topic will be the responsibility of the student in consultation with the academic advisor. When the doctoral student has completed all course requirements for the doctoral degree, together, the student and advisor will propose to the Department Graduate Committee (DGC) a Dissertation Committee. Once approved, the Committee will meet at least as frequently as every six months to review the student's progress. The Committee will assess whether the student is making adequate progress toward completing the dissertation in the required years of study and will approve the dissertation. The student is required to give an oral defense of the dissertation before the Committee and other faculty members.

Requirements for the Doctoral Degree

Degree requirements will generally include 24 to 30 (minimum of 18) credit hours of courses beyond those required for the master's degree. A student with a master's degree from another institution will need to show knowledge in all subject areas required for the equivalent Work Environment master's degree from the University of Lowell.

Courses will be selected so that each student can provide evidence of graduate course work in one major and two minor fields. The major field must include, at a minimum, six full courses, and the minor fields, three courses each. Courses taken for the master's degree may be used to meet these requirements. No language requirement is proposed. The student will work with a doctoral program advisor to propose a set of courses to meet the requirements and to prepare a preliminary thesis proposal.The Graduate Committee will then approve the list of courses and the preliminary proposal.

Following approval of this preliminary program, the student will be eligible to take written qualifying exams. The exams will be designed to test the knowledge in the major and in two minor fields. Exam waivers will require a unanimous vote of the Graduate Committee. Upon meeting the course and written exam requirements, the student must pass an oral qualifying exam based on his or her written dissertation proposal. Following successful completion of the written and oral qualifying exams, a Dissertation Committee will be selected by the Graduate Committee. The dissertation will, in general, be in the form of three publishable manuscripts and will include an appropriate literature review and overview of the dissertation research.

Industrial Hygiene

Likely areas of research include exposure assessment, ventilation system design, aerosol science, chemistry of airborne contaminants, noise control, techniques for reducing the use of toxic chemicals, and respiratory protection. Required courses include at least one of the seminars in the series 19.611-616. A student will normally take two or more of these, depending upon the selected area of research.

Ergonomics

Usually, a student will take two or more of these, depending upon the selected area of research. Examples of areas of doctoral research are field evaluation of ergonomic exposures and hazard surveillance, biomechanical modeling, psychophysical methods of work analysis, evaluation of control measure effectiveness, and technical and social factors in the reorganization of work. Required courses include one or more of the advanced seminars in the series 19.630-19.636 or 19.684. A student will ordinarily take two or more of these, depending upon the selected area of research.

Epidemiology

Required courses include: 19.675, 19.676 and 36.551 (Advanced Pathophysiology). Examples of areas of research in which doctoral work is encouraged include: respiratory epidemiology, injury epidemiology, exposure modeling for epidemiology, occupational disease surveillance, and occupational cancer epidemiology.

Work Environment Policy

Examples of areas of research encouraged for doctoral work are: Labor and Technology, Occupational Standard Setting, Occupational Health and Joint Management Programs, Economic Aspects of Risk Assessment, Health and Safety Impacts of New Technologies, and Management of Chemical Information.

Course Descriptions

19.401 Occupational Health (3-0)3
Prerequisite: Junior or Senior status
Survey of health risks in various work settings to familiarize students with chemical, physical and ergonomic hazards in work environments using a case study approach. Topics addressed include approaches to control or elimination of health risks, health and safety regulation and risk assessment.

19.503 Health Effects of Occupational Exposures (3-0)3
Prerequisite: 30.550 or consent of instructor
Comprehensive review of the toxicology and human health effects of the major chemical and physical hazards encountered in the work environment. The course examines risks associated with heavy metals, organic solvents, harmful dusts, asphyxiants, ionizing radiation, heat stress, noise, and repetitive trauma. Mechanisms of the effects on human physiological systems are described.

19.509 Hazardous Waste Worker Health and Safety (3-0)3
Presents appropriate approaches to protection from health and safety hazards encountered on chemical waste sites and regulation liability, medical surveillance, and waste control policies.

19.510 Industrial Hygiene (3-0)3
An introductory course which surveys industrial hygiene. Topics include the measurement of physical and chemical hazards in the work environment, the design of ventilation and other controls, and the use of personal protective equipment with special attention to respiratory and hearing protection. Not intended for industrial hygiene majors.

19.511 Industrial Hygiene Sampling Lab (0-1)1
Prerequisites: Concurrent or prior enrollment in 19.510 or 19.512
Generally taken with 19.510 to provide introduction to and demonstration of the basic field survey and laboratory measurement equipment needed for the assessment of work environment exposures.

19.512 Exposure Assessment (3-0)3
Prerequisite: 19.510, 19.515 or 19.530; consent of instructor except for designated majors

Concepts of quantification of occupational exposures (chemical, ergonomic, radiation) for purpose of correlating health effects with exposures. Strategies for air sampling, noise measurements, time/motion study and work sampling will be discussed. Topics discussed include reasons for conducting exposure assessment, sampling methods, sampling strategies (for epidemiology, compliance, control), and statistical considerations. Principles are illustrated through a series of case studies.

19.513 Health Hazards of Manufacturing Processes (3-0)3
Prerequisites: Consent of instructor except for designated majors
This course describes the health hazards associated with basic industrial processes. Lectures that describe the processes and their hazards are interspersed with field trips touring typical industrial facilities.

19.514 Aerosol Science (3-0)3
Prerequisite: Consent of instructor for non-industrial hygiene majors
Basic properties of airborne particles, with particular regard to properties important to health. Includes basic properties of gas-borne particles, uniform particle motion, particle collection mechanisms, filtration, particle sampling, respiratory deposition, particle statistics, electrical properties, and optical properties. Course includes lectures and laboratory.

19.515 Measurement of Airborne Contaminants (3-0)3
Prerequisite: Consent of instructor for non-industrial hygiene majors
This course presents basic methods for sampling and measuring the concentration of airborne contaminants. Sampling techniques for gases and vapors are discussed. Basic analytical methods are demonstrated including gas and liquid chromatography, atomic absorption, infrared, fluorescence, and X-ray diffraction spectrometry, and titration.

19.517 Physical Agents: Evaluation and Control (2-0)2
Prerequisite: Consent of instructor except for designated majors
Physical hazards in the work environment include noise, vibration, heat and cold, and ionizing and nonionizing radiation. This course describes each of these hazards and presents the physics underlying their behavior, techniques used to evaluate exposure, and methods of control. Course includes lectures and laboratory sessions.

19.518 Industrial Ventilation (2-0)2
Prerequisite: Consent of instructor for non-industrial hygiene majors
Mechanical ventilation is one of the primary techniques for controlling exposure to airborne contaminants. This course describes the basic types of industrial ventilation systems, principles of design, and methods to evaluate their performance. The course consists of lectures, laboratory, and field sessions.

19.530 Ergonomics and Work (3-0)3
The scientific basis for design of the workplace to optimize physical and mental interaction of workers with machines, tools, and work methods. Topics include work measurement, anthropometry, biomechanics, work physiology, cumulative trauma disorder and information presentation and processing.

19.531 Occupational Biomechanics (3-0)3
Prerequisite: 19.530 or consent of instructor
The anatomical and physiological basis of human motor capabilities. Quantitative models are developed to explain muscle strength performance, motion control, physical fatigue, and acute and chronic musculoskeletal trauma, particularly static link models of lifting and other manual activities. Application of the evaluation and design of various tasks and occupations.

19.531 Laboratory in Occupational Biomechanics (0-1)1
Prerequisite: Taken concurrently with 19.531
Offered in conjunction with the Occupational Biomechanics course, to allow students to experimentally determine 1) musculoskeletal reactions to volitional acts; 2) muscle actions and fatigue, by means of electromyography; and 3) responses of the cardiopulmonary systems to various work stressors.

19.537 Work Physiology (3-0)3
The physiological responses of the cardiopulmonary system to whole-body and local exertions. Physical fatigue, contribution of exertions to heat stress, and psychophysical limits of work tolerance. Quantitative models will be used to estimate metabolic costs of tasks frequently performed.

19.538 Methods in Work Analysis (3-0)3
Prerequisites: 19.530, or consent of instructor
A critical review of traditional industrial engineering approaches to the analysis and prediction of human performance (predetermined time systems, learning curves, work sampling) and modern work analysis techniques to identify and evaluate potential micro- and macro-level ergonomic stressors to the human operator.

19.540 Design for Injury Prevention (3-0)3
Design of tools, equipment, and environment for the elimination or control of occupational safety hazards (industrial machinery, slips/falls/ climbing, enclosed spaces, robotics/automated systems, etc.). Anthropometric analysis, hazard analysis, systems safety, accident investigation and reconstruction, and epidemiologic methods to study acute injury causation.

19.542 Human Factors (3-0)3
Introduction to the functional processes that pertain to human perceptive and cognitive limitations in worker-machine systems. Psychology and physiology (signal detection, memory, sensory performance) in the context of measuring and predicting human performance in the workplace. Principles applied to design of displays, controls, and mental/informational job demands.

19.550 Environmental Law and Policy (3-0)3
Survey of relevant environmental laws and their application to public policy. A framework for understanding environmental politics will be developed. This course is also offered in the Environmental Sciences program as 18.522.

19.551 Work Environment Policy I (3-0)3
This course provides an overview of occupational safety and health policy in the U.S. It focuses on the legal context, especially on OSHA, but also provides an analytical framework for examining the role of social, economic and political factors in the recognition and control of occupational hazards.

19.552 Work Environment Policy II (3-0)3
Prerequisite: 19.551
This seminar is intended to provide students with experience in carrying out a research project on a policy issue under the supervision of a faculty member. Each student will select a project at the beginning and produce a final paper based on original research with an evaluation and analysis of the issues. Meetings will provide opportunity to review progress and permit critical input by students to each other's projects.

19.553 International Occupational Health & Safety (3-0)3
Prerequisite: 19.551
A comparative analysis of occupational health and safety in developed countries. Descriptions and needs of developing countries in occupational health will be reviewed. Issues covered for both will include: surveillance and definition of needs; descriptions of interventions; and programs for primary and secondary prevention activities.

19.554 Labor and Technology (3-0)3
This course examines the broader issues of the impact of technology on the work environment and on workers. Topics include technology and craft work, Taylorism and the development of mass production methods, labor in the "factory of the future", skill-based automation, shop floor programming, and other issues in technology policy.

19.555 Ethics in Occupational Health (3-0)3
Prerequisites: 19.551
This course examines ethical problems of occupational health scientists that derive from the special nature of the workplace environment. Topics include the role of peer review in scientific studies; the influence of funding sources on the conduct of research; problems of industrial hygiene and medical practitioners in the private sector; the significance of scientific uncertainty for ethics; workers "right to know"; and others.

19.556 History and Politics of Occupational Health (3-0)3
Prerequisites: 19.551
A survey of the different pressure groups (industry, labor, government, public) that have played roles in the development of federal and state occupational health activities including: development of workers' compensation, tort law application, public citizen advocacy demands. The resulting public institutions will be studied in terms of the forces which created them and how they have changed in response to changes in the forces.

19.558 Occupational Health Administration I (3-0)3
An introduction to management practices for occupational health and safety specialists. Topics include general program management subjects (business policy and corporate organization, human resources management, accounting and budget management). Special attention will be given to program administration in the public sector. In addition, subjects particularly relevant to occupational health practitioners, such as "right to know",

worker training and health and safety committees will be covered.

19.561 Occupational Health Administration II (3-0)3
Prerequisites: 19.558
This course will analyze the elements of an industrial program to educate workers and supervisors in hazard communication including applicable "right-to-know" laws, and administrative issues concerning chemical, ergonomic, and physical hazards. In addition, the elements of an in-plant toxics use reduction program will be presented describing the activities of toxics reduction planners.

19.562 Joint Occupational Health and Safety Programs (3-0)3
Prerequisites: 19.551
This course studies the history and development of different forms of labor management cooperation in occupational health. The range of function and effectiveness for efforts from in-plant joint committees to corporation/national union joint programs for education and research will be reviewed and evaluated.

19.563 Risk Communication & Management (3-0)3
Prerequisites:19.551
Development of the methods and programs needed for in-plant planners addressing reduction in use of toxic materials, and amelioration of ergonomics and physical hazards. The elements of in-plant risk communication will emphasize effective worker notification of the attendant occupational risks and the evaluation of the impact and effectiveness of communication efforts.

19.570 Introduction to Occupational Epidemiology (3-0)3
Prerequisites: Consent of the instructor for non-majors
Designed as a first course in epidemiology with accompanying biostatistical principles. Major epidemiologic concepts will include measures of disease frequency, rates and risks, standardization, precision and validity, bias, and the important study designs (cohort, case-control and cross-sectional). Case studies will be used.

19.571 Epidemiology Methods II (3-0)3
Prerequisites: 19.570, 19.581 or consent of instructor
An advanced course in epidemiologic methods for those with some background in epidemiology and biostatistics. Topics covered include theory of causal inference, methods of design, analysis and interpretation of epidemiologic studies. Covers the fundamentals of survival analysis, logistic regression in cohort and case control studies, Mantel-Haenszel stratified methods, and the SMR. The assessment and control of confounding through matching, stratification, and multivariate models will be presented.

19.572 Occupational and Environmental Epidemiology (3-0)3
Prerequisites: 19.570, 19.581, or consent of instructor
A course covering both the content and methods of occupational and environmental epidemiology. The students will read and critique numerous studies in the field, and learn the particular methods and difficulties of conducting epidemiologic studies in the work environment. Key concepts include: the standardized mortality ratio and proportional mortality ratio, exposure assessment for epidemiology, and the healthy worker effect.

19.581 Biostatistical Methods for the Work Environment (3-0)3
Prerequisite: Consent of instructor
Introduction to fundamental concepts of probability and statistics, normal and binomial probability distributions, hypothesis testing, confidence intervals, sample size and power calculations, contingency table analysis, correlation and regression analysis.

19.599 Work Environment Seminar (1-0)1
Prerequisite: Enrollment in Department M.S. program.
Weekly seminar presenting current topics of research or applications importance in the field. The seminar will be presented by faculty and invited guests.

19.611 Physical Properties of Aerosols for Exposure Control (3-0)3
Prerequisite: 19.514
A seminar covering aspects of aerosol science not discussed in 19.514 but necessary for the completion of research projects involving aerosols. Topics covered include the electrical, thermal, and optical properties of aerosols, particle agglomeration, evaporation and condensation, and the generation and measurement of test aerosols. Course will consist of lectures and laboratory sessions.

19.612 Industrial Hygiene Exposure Data Analysis (3-0)3
Prerequisite: 19.512
An advanced seminar covering statistical considerations of sampling strategies discussed but not examined in depth in 19.512. Issues such as quantification and partition of sampling variability and evaluation of bias and errors introduced by different assessment strategies will be discussed.

19.613 Design and Evaluation of Ventilation Systems (3-0)3
Prerequisite: 19.518
A seminar intended for students pursuing research involving industrial ventilation system design and evaluation. It covers material not included in 19.518, such as recent theoretical models which describe system performance, design of systems for high-temperature operation, trouble-shooting techniques, and advanced instrumentation techniques. Course consists of lectures and laboratory sessions.

19.614 Advanced Air Chemistry (3-0)3
Prerequisite: 19.515
A seminar intended for students who must utilize advanced techniques for collecting and analyzing air contaminants. Knowledge of advantages and limitations of gas and liquid chromatography, atomic absorption, infrared spectroscopy, and X-ray diffraction will be emphasized through laboratory experiments.

19.615 Methods for Control of Noise and Vibration (3-0)3
Prerequisite: 19.517
A seminar intended for students who are conducting research into the measurement and control of noise and/or vibration. Advanced measurement techniques, analytical methods, and engineering control procedures are discussed. It will be a lecture and laboratory course.

19.616 Design/Evaluation of Respiratory Protection Equipment (3-0)3
Prerequisites: 19.514, 19.518
A seminar intended for students who are conducting research into the design and performance of respiratory protection equipment. Such topics as qualitative and quantitative fit testing, NIOSH certification protocols, workplace protection factors, and research into the design of new respirators will be discussed. Course will consist of lecture and laboratory sessions.

19.630 Research Design for Ergonomics (3-0)3
Prerequisite: 19.530 or consent of instructor
Procedures for conducting research on ergonomics (human factors, biomechanics, etc.). Experimental design alternatives, field research, survey research, considerations of data collection and reduction, sequential design procedures, and ethical use of human subjects.

19.631 Advanced Work Measurement (3-0)3
Prerequisite: 19.538
Criteria for an ideal work measurement method depend in part on the goal of the ergonomic analyses (to identify hazards and recommend control measures; to describe a set of tasks in standardized terms that permit comparison across workplace or industry; to develop a data base of ergonomic exposures for an epidemiologic study). This is an advanced seminar to evaluate and critique existing ergonomic analysis methods, including state-of-the-art developments.

19.632 Advanced Biomechanical Modeling (3-0)3
Prerequisites: 19.531 and consent of instructor
A seminar reviewing current developments in the scientific literature on occupational biomechanics, with special emphasis on three-dimensional and dynamic modeling.

19.634 Cardiopulmonary Effects of Work (3-0)3
Prerequisites: 19.537 and 19.570, or consent of instructor
A seminar reviewing current developments in the scientific literature on work physiology and occupational stress, including both experimental research and epidemiology of cardiovascular and pulmonary disease.

19.636 Ergonomic Stressors and the Pregnant Worker (3-0)3
Prerequisites: 19.570 and 19.530 or 19.537, or consent of instructor
Review of physiology and epidemiology concerning the potential risks associated with ergonomic demands on the pregnant worker. Both maternal health effects (fatigue, low back trauma, acute injury) and fetal effects (spontaenous abortion, gestational age, birthweight, teratogenesis) will be explored.

19.650 Advanced Topics in Risk Assessment/ Risk Perception (3-0)3
This course sets issues of risk assessment and risk perception in a social-psychological framework. Topics will include analysis of cognitive and non-cognitive approaches to risk; worker "subjective" measures of exposure; bureaucratic uses of risk assessment; risk communication; the public health approach to risk; and others.

19.651 Advanced Topics in Regulatory Affairs (3-0)3
This course will be a seminar on key controversial issues in the regulation of the work environment. Topics will include the role of OMB in occupational and environmental health research and regulation, OSHA's shift to personal protective equipment as a primary safety measure, the role of joint health and safety committees and other private approaches to regulation, toxic torts and strict liability, criminal prosecution of environmental offenders, and others.

19.670 Occupational Cancer Epidemiology (3-0)3
Prerequisites: 19.570, 19.571, 19.581 or consent of instructor
This course is a review of current knowledge of carcinogenic risks in the work environment. Covers the historical development of cancer epidemiologic methodology including the multistage model, the scientific basis of the regulatory policy currently in force in the U.S. governing carcinogens, the efficacy of cancer screening, and the use of early markers of genotoxicity in epidemiology.

19.671 Survival Analysis (3-0)3
Prerequisites: 19.570, 19.571, 19.581 or consent of instructor
A detailed study of methods of survival analysis. Students will perform analyses on real data sets using various methods. Computer applications will be emphasized.

19.672 Mathematical Modeling in Epidemiology (3-0)3
Prerequisites: 19.570, 19.571, 19.674, 19.581 or consent of instructor
An advanced course in epidemiologic analysis with emphasis on the design and testing of specialized mathematical models for particular applications. The course will cover: the multistage model of cancer, various models for time-dependent covariates, computation of Robin's G Null statistic, and pharmacodynamic modeling.

19.673 Advanced Epidemiologic Methods (3-0)3
Prerequisites: 19.570, 19.571, 19.674, 19.581 or instructor consent
Biostatistical and epidemiologic methods for the research scientist: the method of maximum likelihood, construction of likelihood functions, empirical Bayes methods, and other special topics tailored to the needs of the enrolled students.

19.674 Multivariate Methods in Epidemiology (3-0)3
Prerequisites: 19.570, 19.571, 19.581, or consent of instructor
The course is an in-depth study of multivariate models for both discrete and continuous outcomes. Topics include: multiple linear regression, logistic regression, and proportional hazards models. Covers methods of checking for violation of underlying assumptions, the construction and interpretation of dummy variables, problems of model selection for causal inference and comparison of alternative models.

19.675 Cohort Design and Analysis (3-0)3
Prerequisites: 19.570, 19.571, 19.581 or consent of instructor
A practical course in the design and analysis of large cohort studies. Traditional person-year methods, survival analysis, nested case control studies, and proportional hazard models are discussed. Methodologic issues in use of both mortality and incidence data are stressed, as are problems of time dependent effects, and use of industrial hygiene data in estimating lifetime exposure histories.

19.676 Case Control Design and Analysis (3-0)3
Prerequisites: 19.570, 19.571, 19.581 or consent of instructor
The theory and practice of the case control study in occupational epidemiology. Covers the selection of cases and controls, matching, interpretation and use of the odds ratio, categorical and multivariate methods of analysis including conditional and unconditional logistic regression.

19.677 Reproductive Epidemiology (3-0)3
Prerequisites: 19.570, 19.571, 19.503, 19.581 or consent of instructor
A course on both the methods and content of research on the reproductive health risks of the work and general environments. Includes a review of reproductive physiology and embryology. Discusses the problems and strategies of collecting reproductive histories, and the use of biologic markers of reproductive status.

19.678 Respiratory Epidemiology (3-0)3
Prerequisites: 19.570, 19.571, 19.581, 19.503 or consent of instructor
An advanced methods course in the collection and analysis of data assessing lung function and diseases. Reviews respiratory physiology, spirometric and radiographic methods, standardized symptom questionnaires, cross-sectional and longitudinal analysis strategies.

19.679 Surveillance and Screening (3-0)3
Prerequisites: 19.570, 19.571, 19.581 or consent of instructor
A seminar on two important advanced topics in occupational epidemiology. Methods of surveillance of the population for identification of cases of disease of probable occupational origin will be discussed. Topics include: sentinel health events, tumor and other disease registration, health hazard evaluation, and problems and prospects of computer linkage of various population data bases. Methodologic problems in screening populations for early disease detection will also be studied. These include: test sensitivity/specificity, lead time bias, and the design of epidemiologic studies to measure the effectiveness of screening programs.

19.680 Issues in Assessment and Control of Confounding (3-0)3
Prerequisites: 19.570, 19.571, 19.572, 19.581
An advanced seminar in confounding in epidemiology. Theoretical and practical aspects of minimizing bias in epidemiologic studies in the face of scientific uncertainty.

19.681 Chemical Exposure Modeling (3-0)3
Prerequisites: 19.570, 19.511, 19.512 or 19.514, 19.581 or consent of instructor
A course stressing the linkage between industrial hygiene and epidemiology. Topics include optimization of industrial hygiene sampling strategies for epidemiologic studies, methods of summarizing industrial hygiene data for epidemiologic models, and the use of pharmacologic modeling in exposure response studies.

19.683 Risk Assessment in Workplace and Environment (3-0)3
Prerequisites: 19.551, 19.570, 19.581 or consent of instructor
This course will review both the methods and policy implications of risk assessment in the development of occupational and environmental standards. Students will conduct risk assessments on real problems, and study important cases in which these methods have been used in setting policy.

19.684 Epidemiology of Musculoskeletal Disease (3-0)3
Prerequisites: 19.570, 19.571, 19.581, and 19.503 or 19.538
An advanced course on methods and content of research on work-related musculoskeletal disorders. Reviews pathophysiology, prevalence, latency considerations, and diagnostic methods. The key literature is examined with attention to study design, quality of exposure assessment, control of bias and adequacy of statistical analysis. Screening and surveillance are also covered.

19.685 Injury Epidemiology (3-0)3
Prerequisites: 19.570, 19.581, 19.530
A seminar covering both the methods and content of studies of the risk factors for acute physical injury in the work environment. Following a review of current knowledge on the subject and models of injury causation, the course will focus on the collection of injury data, measurement of exposure to injury risk factors, and suitable statistical analysis methods. Students will critique the current literature in the field.

19.690 Critical Review of the Scientific Basis of Occupational Health Standards (3-0)3
Prerequisites: 19.503, 19.513, 19.570
Course designed to explore the practical applications of epidemiologic methods to the setting of actual standards. Students gain experience in distinguishing minor from major design and analysis flaws. Course is presented as a seminar with four case studies and problem analysis.

19.711 Selected Topics in Industrial Hygiene (3-0)3
Prerequisites: Specified at the time of offering
Advanced topics in industrial hygiene, exposure assessment or exposure control not offered in the regular curriculum. Topics may vary from year to year.

19.713 Selected Topics in Ergonomics (3-0)3
Prerequisite: Specified at time of offering
Advanced topics in biomechanics, work physiology, occupational safety or human factors not covered in the regular curriculum. Content may vary from year to year.

19.715 Selected Topics in Work Environment Policy (3-0)3
Prerequisites: Specified at the time of offering
Advanced topics in work environment policy, risk perception, risk communication and management, regulatory affairs or labor-management programs

not covered in the regular curriculum. Content may vary from year to year.

19.717 Selected Topics in Occupational Epidemiology (3-0)3
Prerequisites: Specified at the time of offering
Advanced topics in occupational epidemiology, design and confounding, exposure-response modeling, or surveillance not covered in the regular curriculum. Content may vary from year to year.

19.721 Advanced Project in Industrial Hygiene (3-0)3
Advanced research project required of all master's degree candidates electing the non-thesis option in the industrial hygiene concentration.

19.723 Advanced Project in Ergonomics (3-0)3
Advanced research project required of all master's degree candidates electing the non-thesis option in the ergonomics concentration.

19.725 Advanced Project in Work Environment Policy (3-0)3
Advanced research project required of all master's degree candidates electing the non-thesis option in the work environment policy concentration.

19.727 Advanced Project in Occupational Epidemiology (3-0)3
Advanced research project required of all master's degree students electing the non-thesis option in the epidemiology concentration.

19.731 Independent Study in Industrial Hygiene (3-0)3
Directed reading program for a student under the supervision of a specific faculty member.

19.733 Independent Study in Ergonomics (3-0)3
Directed reading program for a student under the supervision of a specific faculty member.

19.735 Independent Study in Work Environment Policy (3-0)3
Directed reading program for a student under the supervision of a specific faculty member.

19.737 Independent Study in Occupational Epidemiology (3-0)3
Directed reading program for a student under the supervision of a specific faculty member.

19.743,6 Work Environment Master's Degree Thesis (3-0)3, (6-0)6
Prerequisites: Minimum 15 credit hours of graduate courses at an acceptable level; approval of a written proposal outlining proposed research work.

19.753, 6, 9 Work Environment Doctoral Dissertation (3-0)3, (6-0)6, (9-0)9
Prerequisites: Minimum of 18 semester hours of graduate courses at an acceptable level; approval of a written proposal outlining the extent and nature of proposed research work.

Department of Industrial Technology

Department Chairperson: Donald S. Pottle, Associate Professor; B.S., M.S., Northeastern University; P.E.
Graduate Coordinator: Richard C. Minesinger, Associate Professor; B.S.E., Princeton University; M.B.A., Case Western Reserve University.
Faculty: David A. Colling, Associate Professor; B.S., M.S., Sc.D., Massachusetts Institute of Technology; P.E.; C.S.P; John D. Colluccini, Assistant Professor; B.S., M.S., University of Lowell; Paul A. Kales, Assistant Professor; B.S., M.S., Northeastern University; P.E.; James G. Keramas, Assistant Professor; B.S., M.S., Athens Polytech; M.Ed., Fitchburg State College; P.E.; Nancy T. Miu, Associate Professor; B.S., National Taiwan University; M.S., North Dakota State University; Sammy G. Shina, Associate Professor; Massachusetts Institute of Technology; M.S., Worcester Polytechnic Institute; P.E.; Edward Simms Jr., Assistant Professor; B.S., Geneva College; M.B.A., Worcester Polytechnic Institute; William G. Sommer, Assistant Professor; B.S., M.S., University of Notre Dame; M.S., University of Pennsylvania; Robert J. Tuholski, Associate Professor; B.S., Fitchburg State College; M. Ed., Ph.D., University of Maryland.

Master of Management Science in Manufacturing Engineering

The process of manufacturing is becoming more sophisticated and more automated. At the same time, industry is faced with managers who have little or no technical training or engineers whose background in the management aspects of the firm is often limited.

The program in Manufacturing Engineering is one that blends technology and management to produce a graduate comfortable in both areas. The program consists of a mix of manufacturing engineering courses and business/management/leadership courses. This course of study is ideally suited for persons following the supervisory or management track within a manufacturing organization. The core courses in the engineering area are intended to broaden perspectives, while the electives offer an opportunity to add to knowledge in specific areas of interest. Likewise, the required courses within the management area are considered essential for enhanced broad understanding, while the elective opens the way for specific insights, according to the needs and interests of the students.

Admission

Applicants must have a B.S. degree in one of the following: Engineering (any discipline), Industrial Technology or Engineering Technology. Students with degrees in other areas are eligible to apply, but may have to complete a substantial number of prerequisite courses before beginning the program.

A student should have had an undergraduate course in each of the following:
- Statistics
- Economics
- FORTRAN (or other high level computer language)

Degree Requirements

The degree will require 30 credit hours (33 for project option) with the study broken up as follows:

Course work	24 credits
Thesis	6 credits
	30 total credit hours

Course work	30 credits
Project	3 credits
	33 total credit hours

Courses will be selected from a number of departments within the Colleges of Engineering, Management Science and Pure and Applied Science. The basic list of selections is shown below. Other courses may be used upon approval by the Graduate Coordinator.

Engineering

A total of 15 credits in engineering subdivided as follows:
Required: 20.516 - Statistical Quality Control
Any two of the following 4 courses:

- 20.515 – Industrial Automation
- 20.525 – Computer Integrated Manufacturing
- 20.530 – Electronic Materials & Fabrication Processes
- 20.572 – Design for Manufacture

Plus an additional 2 electives from the following list:

- 16.521 – Robotics
- 16.522 – Data Structures
- 16.525 – Simulation Techniques
- 19.513 – Health Hazards of Manufacturing Processes
- 19.530 – Ergonomics and Work
- 19.531 – Occupational Biomechanics
- 19.551 – Work Environment Policy
- 20.540 – Systems Concepts in Safety
- 20.550 – Reliability Engineering
- 20.551 – Reliability Analysis of Complex Systems

20.560 – Operation & Management of Industrial Waste Treatment Facilities
20.570 – Advanced Topics in CAD and Robotics
20.580 – Industrial Electro-Optic Design
22.513 – Introductory Finite Element Analysis
26.518 – Plastics Product Design
26.577/
26.578 – Plastics Process Engineering
91.543 – Artificial Intelligence
91.546 – Introduction to Computer Aided Design

Management

A total of 9 credits in management must be chosen from the following:

Required:
60.601 – Financial Accounting
66.651 – Organizational Behavior

Plus one elective from the following group:
20.514 – Engineering Economics
62.601 – Marketing Fundamentals
63.601 – Management Information Systems
63.672 – Operations Management
66.660 – Law & Society

B.S./M.S. Eng. Program

A five-year B.S./M.S. Eng. program is available to undergraduates with a cumulative grade point average of at least 3.0 at the end of their junior year. See description in the front of this catalog.

Course Descriptions

20.514 Engineering Economics (3-0)3
The analysis of economic effects of engineering decisions. Emphasis on the allocation of limited financial resources among competing investment alternatives. Discounted cash flow and internal rate of return methods.

20.515 Manufacturing Automation (3-0)3
Automation strategies, Economic Analysis, High Volume Automation, Automated Flow Lines, Analysis and Balancing, NC, CAD/CAM, process Control Fundamentals and Supervision, Integrated Manufacturing System, Product Design and Assembly Machines.

20.516 Statistical Quality Control (3-0)3
A study of traditional and current statistical techniques which include statistical evaluation, process capability, control charts, sampling plans, correlation, regression analysis and optimization.

20.525 Computer Integrated Manufacturing (3-0)3
Analysis and design of computer integrated systems for planning and controlling of discrete part manufacturing activities. Emphasis on software development for manufacturing, hardware availability and architecture, process planning models and symbology, and different methods of networking.

20.530 Electronic Materials and Fabrication Processes (3-0)3
Semiconductor structure, properties and classification of materials, wafer preparation, bipolar technology, advanced silicon technology, non-silicon technology, electronic packaging of IC, manufacturing and assembly of PC boards and quality assurance inspection.

20.540 Systems Concepts in Safety (3-0)3
Systems concepts in safety, which integrate management, hazard identification and interpersonal relations, are applied to wholistic industrial safety programs and are extended to the construction industry, public safety and catastrophic planning.

20.550 Reliability Engineering (3-0)3
Introduction to reliability and maintainability design techniques, predicting failure rates, data assessment methods, determining MTBF, availability concepts, FMEA, simple reliability models, demonstration testing, government standards and specifications.

20.551 Reliability Analysis of Complex Systems (3-0)3
Application of advanced systems analysis techniques, including Markov models to analyze complex systems that feature multiple redundancy, on-line restoration, fault tolerance, status monitoring, standby equipment with automatic switchover capabilities.

20.560 Operation & Management of Industrial Waste Treatment Facilities (3-0)3
Biological treatment, nutrient addition, physical-chemical treatment, sludge dewatering and disposal, and State and Federal regulations. Primary focus on process control procedures.

20.570 Advanced Topics in CAD and Robotics (3-0)3
Mathematical foundation of advanced CAD Robotics areas. Vector calculus treatment of such topics as geometry, surface/solid modeling, finite element analysis, robot kinematics, dynamics, multi-finger grasp stability.

20.572 Design for Manufacture (3-0)3
The principles of product design important to high volume production and manufacturing. Several systems for assessing assemblability and manufacturability are presented, as well as other techniques such as Axiomatic Theory of Design, Taguchi Method of Robust Design and Tolerance, and Knowledge Based Design.

20.580 Industrial Electro-Optic Design (3-0)3
Introduction to industrial applications of electro-optics. Basic principles of optical theory are presented. Emphasis is on the rapidly growing application to information handling and automation. (For additional course descriptions from other departments, see other appropriate sections of the graduate catalog.)

Department of Mechanical Engineering

Department Chairperson: William Kyros, Professor; B.S., University of Lowell; S.M., Massachusetts Institute of Technology; Ph.D., Cornell University; P.E.

Graduate Coordinator: Yakov M. Zilberberg, Associate Professor; M.S. Technical Institute, Odessa, U.S.S.R.; Ph.D., University of New Hampshire; P.E.

Faculty: Majid Charmchi, Associate Professor; B.S., Arya-Mehr University of Technology; M.S., Ph.D., University of Minnesota; Craig D. Douglas, Associate Professor; B.S., Lowell Technological Institute; M.S., University of Lowell; Sc.D., Massachusetts Institute of Technology; John Duffy, Associate Professor; B.S., Christian Brothers College; M.S., Illinois Institute of Technology; D.Sc., Washington University; P.E.; Turgay Erturk, Professor; B.S., M.S., Middle East Technical University; Ph.D., Drexel University; Richard A. Gaggioli, Professor; B.S., M.S., Northwestern University; Ph.D., University of Wisconsin; C. Zelman Kamien, Associate Professor; B.S., M.S., Ph.D., Purdue University; John McKelliget, Associate Professor; B.Sc., Exeter University, U.K.; Ph.D., Sunderland Polytechnic, U.K.; Alan Mironer, Professor; B.M.E., Rensselaer Polytechnic Institute; M. Eng., Yale University; Ph.D., Syracuse University; P.E.; Mark J. Moeller, Assistant Professor; B.S., Iowa State University; M.S., Ph.D., Massachusetts Institute of Technology; James Moore, Associate Professor; B.S., Rensselaer Polytechnic Institute; M.S., Ph.D., Massachusetts Institute of Technology; Eugene E. Niemi, Jr., Professor; B.S., Boston University; M.S., Worcester Polytechnic Institute; Ph.D. University of Massachusetts; P.E.; John C. O'Callahan, Professor; B.S., M.S., Ph.D., Northeastern University; P.E.; Struan R. Robertson, Associate Professor; B.S., M.S., Clarkson University; Ph.D., Rensselaer Polytechnic Institute; G. Dudley Shepard, Professor; B.S., Yale University; S.M., Sc.D., Massachusetts Institute of Technology; Woon-Shing Yeung, Associate Professor; B.S., University of Lowell; M.S., Ph.D., University of California.

Degree Programs in Mechanical Engineering

Admission Requirements

The admission requirements of the Graduate School are to be followed for all degree programs in Mechanical Engineering. Briefly, the student must submit official transcripts for all prior college level studies, official score report for the Graduate Record Examination Aptitude Test, and three letters of recommendation.

Master of Science in Engineering Degree

The department offers a Master of Science in Engineering program with a thesis or a non-thesis option.

The thesis option requires a minimum of 24 credit hours of graduate courses, 2 credit hours of seminar and 6 credit hours of thesis. The student may only register for research with the prior approval of a thesis advisor. The thesis work is guided by a committee of at least three faculty members including the advisor. Upon completing the thesis the student must orally defend it before the committee and other interested parties.

The non-thesis option requires 33 credit hours of graduate courses and 2 credit hours of seminar.

Regardless of the student's area of specialization, 9 credit hours of core courses in advanced mathematics, thermal-fluid processes and solid mechanics must be taken.

B.S./M.S. Eng. Program

A five-year B.S./M.S. Eng. program is available to undergraduates with a cumulative grade point average of at least 3.0 at the end of their junior year. See the front of the catalog for description.

Doctor of Engineering Degree

The intent of the Doctor of Engineering program is to prepare engineers for leadership positions in industry, government and education. To do so, it combines a rigorous theoretical and technical component with an emphasis on management skill development.

The program of study and a dissertation topic leading to research skill in a specific technical area are planned and developed by the candidate under the guidance of one or more advisors. A significant feature of this program is the option to carry out the dissertation research in an approved industrial or governmental establishment as well as at the University.

Admission Requirements

The admission requirements of the Graduate School are to be followed. The applicant must have a B.S. degree in mechanical engineering or its equivalent and a minimum grade point average of 3.0. An applicant with an M.S. degree in mechanical engineering or its equivalent may apply and transfer up to 24 credit hours toward the doctoral degree. In cases where a student has an M.B.A. in addition to a B.S. in mechanical engineering, the management part of the Doctor of Engineering program may be waived.

Degree Requirements

The overall requirements are:

1. 42 credit hours of graduate level engineering and mathematics courses including the core requirement of Solid Mechanics I, Fundamentals of Thermal Fluid Processes, and a two course sequence in advanced mathematics such as Partial Differential Equations I & II;
2. 2 credit hours of Doctoral Seminar;
3. 16 credit hours of D. Eng. management courses;
4. 30 credit hours for the dissertation research;
5. The student must be in full-time residency at the University for at least one year;
6. The student must have a minimum grade point average of 3.25 in order to graduate.

A student is required to take the qualifying examination at the beginning of his or her second semester in the program. An exception will be made for a student whose undergraduate background was not in mechanical engineering. A student may not register for research until he or she has passed the qualifying examination and has the approval of the advisor. A student may register for no more than six (6) credit hours of research in preparing a formal thesis proposal. This proposal and the student's ability to perform the research must be orally defended before the student's doctoral committee and other interested parties. This constitutes the candidacy examination. Upon passing this and completing all course requirements, the student becomes a candidate for the D.Eng. degree and may register for additional research credit with the advisor's approval.

Qualifying Examination

I. This examination consists of a written part and an oral part. The student is given two (2) attempts at passing the exam. A student who does not take the exam at the expected time may lose all financial support, if any. Such a student will be permitted to take the exam only once, and that one attempt must be the next time the exam is offered.

II. The written part is closed book and has two sections each of three hours duration. One section covers statics, strength of materials, dynamics and vibrations. The other section covers thermodynamics, fluid mechanics and heat transfer. The exam is evaluated by the Graduate Examination Committee, which decides whether or not a student shall be eligible to take the oral part.

III. A student who has passed the written part of the exam will take the oral part no later than 10 weeks afterward.

IV. The oral examining committee will report its assessment of the student's performance to the Graduate Faculty of the Department for the final decision as to whether or not the student passed the entire qualifying exam.

V. A student who fails may be permitted by the Graduate Faculty of the Department to take the exam a second and final time in the following year.

Dissertation

The research work for the dissertation shall be carried out under the supervision of a graduate faculty advisor and a committee of at least two other graduate faculty members. In addition, if the work is carried out in an approved industrial or governmental establishment a technical advisor from that establishment must be on the committee. Such a technical advisor must satisfy the criteria for appointment to the regular faculty and be approved by the Mechanical Engineering Department.

More detailed information may be found in the Doctor of Engineering Student Handbook for the Mechanical Engineering Program.

Ph.D. Degree in Applied Physics

A program offering a Ph.D. in Applied Physics with an option in Applied Mechanics is offered jointly by the Departments of Physics and Mechanical Engineering. This program is described in detail in the Physics section of this catalog.

Course Descriptions

22-501 Graduate Seminar in Mechanical Engineering (1-1)0
A required weekly seminar intended to develop the oral communication skills of the student and an awareness of the research within the department. This seminar series is aimed at the master's level student. Each student will present a 20-minute seminar each semester.

22-511 Matrix Methods in Engineering Mechanics (3-0)3
Matrix linear algebra, factorization of simultaneous equations, direct and iterating eigenanalyses, FORTRAN programming and algorithm development, solutions in structural analysis, dynamics and stability using program MATRIX.

22-512 Structural Dynamics (3-0)3
Mass, damping and stiffness matrix development, static and dynamic condensation techniques, eigensolutions using MATRIX and structural analysis programs, modal superposition, maximum response analysis, direct integration of motion equations, non-proportional damping.

22-513 Introductory Finite Element Analysis (3-0)3
The course covers matrix algebra, direct stiffness approach, Galerkin's method and the principle of minimum potential energy. One dimensional

mechanical, fluid and thermal problems are analyzed.

22-514 Finite Element Analysis (3-0)3
Prerequisite: 22-513, 562
Direct and variational methods are used to derive equations for structural and continuum elements. Static, dynamic and vibration problems are analyzed. The student also writes a small finite element program.

22-515 Modal Analysis I - Theory (3-0)3
System modeling using analytical and experimental techniques, frequency response functions, single and multiple dot curve fitting techniques, Fourier series and transform methods, DFT and FFT signal processing analysis.

22-516 Modal Analysis II - Experimental (3-0)3
Measurements using FFT based modal analyzers, structural modal surveys using impact and sine-sweep excitations, analytical modeling of test system, rotary of estimation, complex modes, optimization of system matrices, structural modification procedures.

22-518 Signal Processing Techniques (3-0)3
Course addresses the statistical processing of random vibration data. Fourier analysis and spectral concepts are presented. Correlation and coherence are discussed. Frequency response functions are introduced.

22-519 High Frequency Vibrations & SEA (3-0)3
Energy description of random vibration in structures, autocorrelation and spectral density functions. Energy sharing between coupled systems, the basic theory of SEA, engineering applications of the SEA methodology.

22-541 Fundamentals of Thermo-Fluid Processes (3-0)3
Governing equations (thermodynamic transport and kinetic); types of models; modes of solutions; data requirements and sources. Applications: fluid flow, heat and mass transfer, chemical reactions.

22-542 Advanced Engineering Thermodynamics (3-0)3
A comprehensive treatment of the first and second law. Availability, static & dynamic irreversibility, equilibrium, heterogeneous systems, mixtures and solution. Analysis of energy destruction. Chemical equilibrium. Introduction to statistical methods.

22-543 Convective Heat and Mass Transfer (3-0)3
Prerequisite: 22-541
Review of conservation equations. Heat transfer in laminar and turbulent boundary layer and duct flow. Free convection. Convective mass transfer.

22-544 Conduction and Radiative Heat Transfer (3-0)3
Steady and unsteady heat conduction: analytical and numerical solutions. Radiative heat transfer between surfaces and participating media.

22-545 Combustion (3-0)3
Prerequisite: 22-541
Thermodynamics of combustion. Dynamics of pre-mixed and diffusion flames: ignition and extinction; flame propagation; combustion of solid and liquid fuels. Fire problems.

22-546 Energy Conversion (3-0)3
Concepts of thermodynamics pertaining to energy conversion; irreversible thermodynamics. Solid-state phenomena involved in conversion processes; energy forms, equations of states and energy fields. Selected topics in direct energy conversion systems.

22-547 Thermodynamic Analysis of Energy Systems (3-0)3
Prerequisite: 22-541
Second Law methods for pinpointing, quantifying and costing inefficiencies in energy transfer and conversion systems, for improved and/or optimized systems operation and design. Fundamentals of thermoeconomics.

22-548 Design, Simulation and Optimization of Energy Systems (3-0)3
Prerequisite: 22-441 or permission of instructor.
Mathematical modelling of energy-conversion devices and systems; development of computer simulations, and use of proprietary codes. Methodologies for systematically improving and optimizing system operation and design: Second Law costing, Lagrange multipliers, search methods; dynamic, geometric, and linear programming.

22-550 Vibrations (3-0)3
Prerequisites: 22-354, 92-301
Modeling and solution of multi-degree of freedom problems. Matrix methods are used along with an applications program. Shock spectrum methods and non-linear effects are considered.

22-552 Vibrations of Continuous Media (3-0)3
Prerequisites: 22-562, 92-545
Propagation of disturbances in continuous media including: strings, beams (bending, torsion, and longitudinal deformations), plane waves in air and an elastic media, modal descriptions of systems with finite impedance boundaries. Energy transmission and reflection at discontinuities.

22-553 Random Vibration (3-0)3
Random processes; probability, time and ensemble averages, time correlation and power spectra. Applications to excitation and response of multiple input dynamic systems.

22-554 Dynamic Systems and Control (3-0)3
Matrix-based classical and modern approaches to dynamics and automatic control of hydraulic, thermal, electro-mechanical and structural dynamic systems with multiple inputs and outputs.

22-555 Fundamentals of Noise Control (3-0)3
Fundamental acoustic theory and measurement are presented. Barriers and sound absorption for control of airborn noise, vibration isolation and damping for structural noise are discussed.

22-556 Stochastic Processes (3-0)3
Introduction to stochastic processess with emphasis on time domain analysis. Probability theory, continuous and discrete joint distributions, moments. Gaussian, Markov, stationary, Poisson processes. Queueing theory, noisy dynamic systems, time series analysis, Kalman filtering, geometric foundations. Inferential statistics and experimental design. A wide variety of applications.

22-557 Principles of Underwater Acoustics (3-0)3
This course will cover the fundamentals of underwater acoustics with emphasis on sonar system applications.

22-561 Continuum Mechanics (3-0)3
Stress and deformation in a continuum in tensor notation. Fundamental laws of mechanics and thermodynamics. Application to elastic, viscous, and viscoelastic substances.

22-562 Solid Mechanics I (3-0)3
The linear theory of elasticity is introduced followed by calculus of variations which is used as a tool for developing the variational principles of mechanics. Applications in structural mechanics include the study of torsion, beams, plates and shells.

22-563 Solid Mechanics II (3-0)3
Prerequisite: 22-562, 92-545
Corequisite: 92-546
Topics covered will include buckling, thermal stress, wave propagation and finite deformation.

22-564 Plates and Shells (3-0)3
Prerequisite: 22-562, 92-545
Solutions to bending, buckling and vibration problems are obtained for rectangular and circular plates. The membrane theory of shells as well as the general theory is investigated and solutions are obtained for a variety of practical shell problems.

22-581 Advanced Fluid Mechanics (3-0)3
Corequisite: 92-545
Fundamental equations of fluid motion, kinematics, vorticity, circulation, Crocco's theorem, Kelvin's theorem, Helmholtz's vorticity laws, secondary flows. Stream function, velocity potential, potential flows. Unsteady Bernoulli equation, gravity water waves.

22-582 Viscous Flow (3-0)3
Prerequisite: 22-581
Derivation of Navier-Stokes equations. Examples of exact solutions. Laminar and turbulent boundary layer. Low Reynolds number flow.

22-583 Advanced Topics in Aerodynamics (3-0)3
Application of aerodynamic principles to one of the following topics: helicopter rotor aerodynamics, rocket flight, or aircraft performance. Topics may vary from year to year.

22-584 Two-Phase Flow (3-0)3
Fundamental development of one-dimensional two-phase flow. Homogenous flow, separated flows, drift flux model. Applications: gas-solid systems, gas-liquid systems, nuclear technology, wave propagation.

22-585 Turbulent Flow (3-0)3
Prerequisite: 22-541
Concepts of turbulence. Mixing length theory. Classical turbulent boundary layer, pipe and wake flows. Advanced turbulent models, and measurement techniques.

22-586 Computational Fluid Mechanics and Heat Transfer (3-0)3
Prerequisite: 22-541
Fundamentals of finite difference schemes: stability, consistence, accuracy. Spectral and Galerkin's methods.

22-587 Application of Special Numerical Methods in Thermo-Fluid Systems (3-0)3
Prerequisite: 22-541
Application of state-of-the-art numerical methods to the solution of problems involving fluid flow, heat transfer, chemical reaction and turbulence.

22-591 Mechanical Behavior of Materials (3-0)3
An examination of the deformation and fracture mechanics of engineering materials. Topics include tensile response, elements of dislocations and slip, high temperature deformation response of crystalline and viscoelastic materials; elements of fracture mechanics.

22-592 Theory of Dislocations (3-0)3
Prerequisite: 22-591 or permission of instructor
Dislocations in continuous media. Dislocations in crystals. Defects in crystals. Obervation of dislocations. Elastic properties of dislocations. Dislocations in fcc, bcc, hcp and NaCl structures. Multiplication and intersection of dislocations. Dislocation arrays. Dynamics of a dislocation line. Strengthening mechanisms such as solid solution, precipitation, strain, and particle hardening. Dislocation modeling of mechanical behavior.

22-594 Fracture Mechanics (3-0)3
The understanding and prevention of fracture of engineering materials requires an integration of basic concepts in material science and solid mechanics. Focuses on connecting basic microstructural fracture processes, such as cleavage, void initiation, growth, and coalescence, with appropriate quantitative macroscopic models. Topics: linear elastic fracture mechanics; elastic-plastic fracture mechanics; fatigue and fatigue crack growth; creep rupture and creep crack growth; fracture of bimaterial interfaces.

22-595 Fracture Mechanisms in Materials (3-0)3
Prerequisite: 22-594 or Permission of Instructor
Fracture and toughening mechanisms in all prominent structural solids. Ideal strength. Brittle fracture in tension and compression. Statistics of fracture. Static fatigue. Environmental effects. Toughening by crack tip shielding. Brittle-to-ductile transition. Relation to dislocation mechanics. Fracture of composites. Martensite, fiber and microcrack toughening of ceramics. Craze toughening of glassy polymers.

22-596 Composite Materials (3-0)3
The mechanical behavior of orthotropic materials is reviewed. Methods of analyzing orthotropic lamina and laminated composites are introduced. Important methods of fabrication and testing of composites are covered. Other topics include environmental effects, joining and machining.

22-597 Structural Application of Composite Materials (3-0)3
Prerequisite: 22-562 or 22-564, 22-596
Study of constitutive relationships for anisotropic materials and application of these materials to structural elements such as beams, plates and shells. Problem areas considered include bending, buckling, and vibrations.

22-598 Metallic and Ceramic Composites (3-0)3
The understanding and application of fiber reinforced composites requires an integration of basic concepts in material science and solid mechanics. Although the fundamental principles of fiber reinforcement are identical for all composites, metallic and ceramic composites deviate from polymer matrix composites in behavior and purpose. This course focuses on both fundamentals of fiber reinforcement and characteristics of different kinds of composites, trying to unify the field of composite materials. Topics to be discussed include fibers and matrix materials, critical interface phenomena, fabrication processes, anisotropy of elasticity, strength, and thermal expansion, fracture and damage mechanics, and environmental effects.

22-601 Special Topics in Mechanics (3-0)3
Advanced topics in mechanics not covered in the regular curriculum. Content may vary from year to year.

22-602 Special Topics in Thermo-Fluids (3-0)3
Advanced topics in thermo-fluids not covered in the regular curriculum. Content will vary from year to year.

22-606 Directed Study (3-0)3
This gives the student the opportunity to learn material of an advanced nature in the format of a tutorial.

22-733 Advanced Project in Mechanical Engineering (3-0)3
Prerequisite: Permission of instructor
Advanced project not for thesis.

22-743 Thesis Research for M.S. Eng. (0-3)3

22-746 Thesis Research for M.S. Eng. (0-6)6

22-753 Doctoral Dissertation Research (0-3)3

22-756 Doctoral Dissertation Research (0-6)6

22-759 Doctoral Dissertation Research (0-9)9

Department of Plastics Engineering

Department Chairperson: Nick R. Schott, Professor; B.S., University of California, Berkeley; M.S., Ph.D., University of Arizona.
Graduate Coordinator: Rudolph D. Deanin, Professor; A.B., Cornell University; M.S., Ph.D., University of Illinois.
Doctoral Program Coordinator: Fang S. Lai, Associate Professor; B.S., National Taiwan University; M.S., University of Notre Dame: Ph.D., Kansas State University.
Faculty: S. J. Chen, Professor; B.S., National Taiwan University; M.S., California Institute of Technology; Ph.D., Kansas State University; Aldo M. Crugnola, Professor and Dean of the College; A.B., Boston University; M.S., Northeastern University; Sc.D., Massachusetts Institute of Technology, P.E.; Stephen B. Driscoll, Professor; B.S., M.S., Lowell Technological Institute; Steven J. Grossman, Associate Professor; B.S., University of Connecticut; Ph.D., University of Massachusetts; Jan-Chan Huang, Associate Professor; B.S., National Taiwan University; Ph.D., University of Wisconsin-Madison, P.E.; Robert A. Malloy, Asssistant Professor; B.S., M.S., Ph.D., University of Lowell; Stephen P. McCarthy, Associate Professor; B.S., Southeastern Massachusetts University; M.S.E., Princeton University; Ph.D., Case Western Reserve University; Robert E. Nunn, Professor; B.Sc., London University; A.C.G.I., Imperial College; D.I.C., Imperial College; Ph.D., London University; Stephen A. Orroth, Jr., Professor; B.S., M.S., Lowell Technological Institute; Stephen P. Petrie, Professor; B.S., M.S., Lowell Technological Institute; Ph.D., University of Connecticut; Amad Tayebi, Professor; B.S., Alexandria University; S.M., M.E., Sc.D., Massachusetts Institute of Technology.

Master of Science in Engineering Degree Program

The graduate program offers professional training at the master's level designed to provide the opportunity for the study of more advanced theory and practice in plastics, man made fibers, coatings, and adhesives, and to broaden the background of experienced members of the profession and to help them keep up with the latest fundamental developments in the field.

The Department of Plastics Engineering offers Master of Science in Engineering degrees in Plastics and Plastics Engineering. In addition, the department offers master's degrees in the following five options: plastics materials, design, processing, fibers/composites, and coatings and adhesives. A Master of Science in Engineering degree will be awarded upon satisfactory completion of 30 credit hours of study, of which the mandatory thesis provides 6 credits.

Admission Requirements

Admission to the program is open to candidates with a B.S. in plastics engineering or a related field. Candidates with degrees in other fields of science or engineering, from other schools, or industrial experience in place of University of Lowell B.S. courses in plastics, will take the undergraduate courses they lack as prerequisites before undertaking the graduate courses in plastics. The Graduate Record Examination Aptitude test is required for this program, but not the Advanced test.

Advisors and Advisory Committee

The program coordinator will be the academic advisor for each student, to help him or her remedy deficiencies in prerequisites, select electives of most value, and plan the overall study program efficiently. The thesis advisor will be chairperson of the thesis advisory committee, which will guide the student in the thesis research and supervise the completion of the thesis requirement.

Plastics and Plastics Engineering

Students with a B.S. in Plastics Engineering may earn an M.S. Eng. in Plastics Engineering by the following course of study:

26-5XX	Electives	22 Credits
26-701/702	Plastics Seminar	2
26-743	Graduate Research and Thesis	6

This should normally take three semesters of full-time study.

Students with a B.S. in other fields of science or engineering may earn a Master of Science in Plastics by making up the following prerequisites in addition to the above program:

Polymer Science
Polymeric Materials
Mechanical Behavior of Polymers
Physical Properties Laboratory
Process Engineering
Processing Laboratory

Students with a B.S. in science may earn a Master of Science in Engineering in Plastics Engineering by also making up as well any missing prerequisites in mathematics and general engineering. This should normally take a total of four semesters.

B.S./M.S. Eng. Degree Program

A five-year B.S./M.S. Eng. program is available to undergraduates with a cumulative grade point average of at least 3.0 at the end of their junior year. See the front of the catalog for description.

Plastic Materials Option

Required Courses

26-503	Mechanical Behavior of Polymers	3
26-506	Polymer Structure, Properties, and Applications	3
26-701/2	Graduate Seminar I/II	2
84-403/4	Polymer Science I/II	6
26-703/4	Plastic Materials Seminar	1
		15

Choose two of the following:

26-516	Composite Materials	3
26-583	Research Methodology	3
26-533/4	Coating Science and Technology	6
26-536	Rheology of Coatings	3
26-535	Rubber	3
26-559	Elements of Packaging	3
26-553/4	Polymers in Medicine I/II	6
26-513	New Plastic Materials	3
26-511	Polymer Blends	3
26-532	Adhesives	3
26-512	Foams	3
26-565	Engineering Polymers	3
26-566	Polymeric Materials Systems Selection	3
26-555/6	Rheology I & II	6
26-540	Commercial Development of Polymers	3
		6
Plus one elective 26.5XX		3
Plus Thesis Research in Plastics Materials		6
	TOTAL	30

In addition - for students with a non-plastics B.S.:

26-543	Survey of Plastics Materials I	3
26-544	Survey of Plastics Materials II	3
26-577	Plastics Processing Engineering I	3
26-578	Plastics Processing Engineering II	3
26-571/2	Plastics Processing Eng. Lab. I/II	2
26-573/4	Plastics Physical Prop. Lab. I/II	2
		16

Design Option

Required courses:

26-503	Mechanical Behavior of Polymers	3
26-506	Polymer Structure, Properties, and Applications	3
26-518	Plastic Product Design .	3
26-585	Computer Aided Engineering and Design	3
26-705/6	Design Seminar	1

Choose two of the following:

26-701/2	Graduate Seminar	1
26-703/4	Materials Seminar	1
26-707/8	Processing Seminar	1
		15

Choose three of the following:

26-509	Plastics Processing Theory	3
26-552	Design of Polymer Processing Machinery	3
26-523	Plastics Process Design	3
26-576	Advanced Mold Design	3
26-586	Computer Aided Engineering and Design II	3
84-403	Polymer Science (or 97-503)	3
26-5XX	Elective (other dept's graduate courses by petition)	3
		9
Thesis Research in Plastics Design		6
	TOTAL	30

In addition - for students with a non-plastics B.S.:

26-543	Survey of Plastics Materials I	3
26-544	Survey of Plastics Materials II	3
26-577	Plastics Process Engineering I	3
26-578	Plastics Process Engineering II	3
26-571/2	Plastics Process Engineering Lab I/II	2
26-573/4	Plastics Physical Properties Lab I/II	2
		16

Processing Option

Required Courses

26-506	Polymer Structure, Properties & Applications	3
26-509	Polymer Processing Theory I	3
26-510	Polymer Processing Theory II	3
26-552	Design of Polymer Processing Machinery	3
26-703/4	Materials Seminar	1
26-705/6	Design Seminar	1
26-707/8	Processing Seminar	1
		15

Choose three of the following:

26-518	Plastic Product Design	3
26-523	Plastics Process Design Analysis	3
26-524	Process Control	3
26-557	Composites Fabrication	3
26-583	Research Methodology (Design of Exp.)	3
26-585	Computer Aided Engineering and Design	3
26-5XX	Elective	3
		9
Plus Thesis Research in Plastics Design		6
	TOTAL	30

In addition - for students with a non-plastics B.S.:

26-543	Survey of Plastic Materials I	3
26-544	Survey of Plastic Materials II	3
26-577	Plastics Process Engineering I	3
26-578	Plastics Process Engineering II	3

26-571/2	Plastics Process Eng. Lab I/II	2
26-573/4	Plastics Physical Properties Lab I/II	2
		16

Fiber/Composites Option

This specialized course of study is designed to prepare prospective Master of Science in Engineering candidates for careers in the reinforced plastics and advanced composite materials industries. As technology advances, the demands on the performance of existing materials outstrip the ability to meet the new requirements. These demands necessitate the search for new materials with improved properties and a need for engineers who can address this challenge. Thus, the need for this program is driven by the advancing state of the art of materials technology and engineering in terms of the characterization, processing and application of new materials.

Because of its strong focus on engineering and science the Department of Plastics Engineering has an array of facilities and ongoing activities in materials that have been organized to offer this program in fibrous composite materials. The program offers professional study in the areas of fiber production to fiber reinforced composite materials; their design, analysis, and fabrication as well as the design of machines for their fabrication.

Admission to the Program

Admission to the program is open to all students posessing undergraduate degrees in plastics engineering and also to those holding undergraduate degrees in plastics, textile engineering or other applicable fields of study such as mechanical or chemical engineering, applied physics or chemistry. The student's advisor will review his or her background to determine any need for further prerequisites. Students with a B.S. in fields other than plastics may earn an M.S. in the Plastics Engineering/Fiber-Composites Option by making up prerequisites in the polymer area. In general, students who do not hold undergraduate degrees in engineering are required to fulfill the following prerequisite requirements.

Prerequisites for students holding the B.S. in Science:

- Calculus (three semesters)
- Differential Equations
- Physics (two semesters)
- Analytic Mechanics (two semesters)
- Materials Science & Engineering
- Fluid Mechanics
- Thermodynamics
- Electricity
- Heat Transfer
- FORTRAN

ULAA Scholarships/Research and Teaching Assistantships

The University of Lowell Alumni Association awards four $500.00 scholarships to graduate students majoring in the Fiber/Composite Materials Option. Students may apply for the scholarship to the program coordinators after the submission, and acceptance by a faculty member, of a relevant thesis proposal. A limited number of teaching and research assistantships are available with stipends plus tuition waiver to qualified second year graduate students.

Course of Study

The curriculum includes seventeen (17) units of common/core courses, two (2) units of seminar, nine (9) units of recommended electives and a six (6) unit thesis in an area of fibers/composite materials.

Core Courses (17 Units)

26-503	Mechanical Behavior of Polymers	(3-0)3
26-509	Plastics Processing Theory	(3-0)3
26-516	Composite Materials	(3-0)3
26-525	Proc. of Syn. Fibers & Fibrous Struct.	(4-0)4
26-527	Mechanics of Fibrous Structures	(3-0)3
97-505	Polymer Prep. & Characterization	(0-4)1
26-701/2	General Seminar I/II	(2-0)2

Elective Courses (9 units)

26-504	Physical Properties of Polymers.	(3-0)3
26-506	Polymer Structure/ Props./Appl.	(3-0)3
26-526	Adv. Proc. Syn. Fibers & Fibrous Struct.	(3-0)3
26-529	Evaluation of Advanced Textile Structures	(2-2)3
22-597	Structural Applications of Composites	(3-0)3
22-598	Case Studies in Composites	(3-0)3
26-552	Design of Polymer Proc. Mach.	(3-0)3
97-503	Advanced Polymer Science I	(3-0)3

Coatings and Adhesives Options

A complete curriculum in Coatings and Adhesives is open to graduates in chemistry, chemical engineering, coatings, plastics, or related fields, with experience or interest in the coatings and adhesives fields. The following curriculum is recommended:

26-533/4	Coatings Science and Technology I and II	(3-0)(3-0)6
84-403/4	Polymer Science I and II	(3-0)(3-0)6
84-405/6	Polymer Preparation and Characterization I & II	(0-4)(0-4)2
26-503	Mechanical Behavior of Polymers	(3-0)3
26-536	Rheology of Coatings	(3-0)3
26-532	Adhesives and Adhesion	(3-0)3
26-701/2	Seminar	(1-0)(0-1)2
26-743,6	Graduate Research: Thesis	(0-9)(0-9)3, 6

Considering the varying background and interests of individual students, this basic curriculum can, of course, be modified by agreement between the student and his or her Advisory Committee.

Doctor of Engineering Degree Program

The Doctor of Engineering in Plastics Engineering is designed to produce qualified professionals for technical management positions in the plastics industry, as well as for administrative positions in government and for teaching careers in colleges and universities. Each year the department publishes a Doctor of Engineering Student Handbook, in which details of current requirements of the program are given. These rules are summarized below.

Objective

The goal of the Doctor of Engineering program is to develop decision-making engineers with sound theoretical and technical research knowledge who are design and development oriented and who also have a firm background in engineering management. This interdisciplinary program encompasses study in design, mathematics, computer science, operations research, and management.

Admission Requirements

Graduates with a B.S. in Plastics Engineering and high academic standing may apply to the Graduate School for admission to the program. Graduates from other schools or in other fields of engineering will be required to make up any prerequisites which they lack in comparison to the B.S. Plastics Engineering curriculum at the University of Lowell. Technical graduates who do not have a B.S. in engineering may request admission to the program, on the understanding that they will also be required to make up the general mathematics, science and engineering courses which they lack. Applicants must submit official transcripts of all prior undergraduate and graduate courses. Each applicant must also submit the official score report of the Graduate Record Examination Aptitude test. The TOEFL score is required for students from abroad whose native language is not English. Admission to the program will be

based on review by the Graduate School and by the Admissions Committee of the Plastics Engineering Department.

Plan of the Program

Each student entering the program must develop a plan of study in consultation with his or her advisory committee. After satisfying the prerequisites and taking one year of graduate courses, the student will take a qualifying examination covering all the basic elements of plastics engineering. A student who performs well on this examination will be reviewed by the Admissions Committee of the Plastics Engineering Department. A student who satisfies these two criteria will be admitted to candidacy for the degree. He or she will then complete the remaining course work, seminars, internship, dissertation, and oral defense of the research.

Qualifying Examination

The qualifying examination will be administered twice a year in May and September. It will be a day-long examination, covering the following topics: plastics materials, mechanical behavior, testing, processing and processing theory, plastics industry organization, and engineering mathematics. The student will receive a grade of pass or fail. A student who fails the exam on a marginal basis may make a second attempt with permission of the Graduate Study Committee. All decisions of the Plastics Engineering Department regarding passing of the qualifying exam are final.

Dissertation Proposal

Once the student has passed the qualifying exam, he or she may submit a dissertation proposal and defend the proposal before the Doctoral Committee. Upon approval, the student's name will be submitted to the College Doctoral Committee and the Dean of the Graduate School as a candidate for the Doctor of Engineering degree. Admission to candidacy status does not guarantee awarding of the degree.

Transfer Credit

Up to 24 credits in graduate engineering courses are transferable to the Doctor of Engineering program upon approval by the department's Doctor of Engineering Committee.

Language Requirements

The student must demonstrate satisfactory reading ability (level two) in one foreign language (French, German, Japanese, or Russian) which is not the student's native tongue. The language requirement may be satisfied by:

a. Passing an examination given by the Doctor of Engineering Committee of the department with the advice and cooperation of the Department of Languages.
b. Completing a one-year course beyond the first year with a grade of B or better.

Internship and Dissertation

Each student will be required to complete an internship of one year's duration in either industry, government or the University. The purpose of the internship is to place the student in a realistic engineering setting in which he or she will function as a high level engineer and carry out the work required for his or her dissertation. During the internship the student will maintain close contact with the academic advisor. The student will have, in addition, a close working relationship with the advisor provided by the organization sponsoring the internship. The dissertation problem will be design or development oriented, using these terms in their broadest engineering meanings.

The student will prepare a complete written dissertation on his or her internship, and make an oral defense to the advisory committee, which will include a representative from the staff of the internship organization. This defense will be open to the university community.

Other Requirements

A student must maintain high academic standing throughout the pursuit of the degree. He or she must spend at least one year at the University with full-time graduate student status, in addition to the internship requirement.

Course Requirements

The following courses are required for the degree:

26-503	Mechanical Behavior of Polymers	3
26-506	Polymer Structure, Properties and Applications	3
26-509/10	Plastics Processing Theory I/II	6
26-513	New Plastic Materials	3
26-518	Plastic Product Design	3
26-541	Computer Applications in Plastics	3
26-547/48	Mathematical Techniques & Numerical Techniques	6
26-585/86	Computer Aided Engineering and Design	6
26-701/2	Plastics Seminar	2
	Engineering Electives	8
	Engineering Management Courses and Seminar	17
	Total course credits	60
	Internship and Dissertation	30

A student who has already covered any of this material may substitute other engineering electives, with the advice and approval of the advisory committee. A student who has taken any of these courses toward the Master of Science degree may apply them toward the Doctor of Engineering degree as well.

Doctor of Philosophy Degree Program

A doctoral program in Chemistry with an option in Polymer Science/ Plastics Engineering is offered jointly with the Polymer Science group in the Department of Chemistry. This program is designed to provide the student with a background in advanced course work and laboratory techniques that will prepare him or her to carry out, under the guidance of experienced scientists, an original, independent investigation that will lead to an acceptable contribution to the body of contemporary knowledge. Further details of the program are described in the Chemistry section of this catalog.

Course Descriptions

26-502 New Plastics Processing Techniques* (3-0)3
Critical examination of new plastics processing techniques appearing in the research literature and being commercialized in the plastics industry.

26-503 Mechanical Behavior of Polymers (3-0)3
Mechanical properties of bulk polymers. Linear viscoelasticity, creep, relaxation, dynamic and stress/strain response phenomena. Principles of time/temperature superposition. Rubber elasticity. Failure behavior of polymeric materials.

26-504 Physical Properties of Polymers* (3-0)3
Polymers as linear viscoelastic materials. Creep, stress relaxation, superposition, dynamic mechanical behavior, electrical behavior, miscellaneous mechanical properties, optical properties, transport properties.

26-506 Polymer Structure, Properties, and Applications (3-0)3
Relationships between polymer structure (chemical composition, molecular weight and flexibility, intermolecular order and bonding, supermolecular structure), practical properties (mechanical, acoustic, thermal, electrical, optical and chemical) and applications.

26-507 Plastics Industry Organization (3-0)3
Economics of producing plastic raw materials and converting them into end products, from research and development to plant construction and marketing. Market analysis of plastics production, processing, and consumer patterns; commercial development, sales, and technical service.

26-509/510 Plastic Processing Theory (3-0)(3-0)6
Principles of heat transfer, rheology, mixing, crystallization, and chemical reactions involved in the

processing of plastics, and their applications to plastics process engineering.

26-511 Polymer Blends and Multiphase Systems* (3-0)3
Physical, mechanical and thermal properties, preparation, and testing of polymer blends, alloys, and multiphase systems. Thermodynamic theories and experimental determination of miscibility of polymer blends. Structure-property relationships for multiphase systems and interpenetrating networks.

26-512 Plastics Foams* (3-0)3
Preparation, structure, and properties of plastics foams. Practical systems in development and production. Properties, applications, and markets for plastics foams and products made from them.

26-513 New Plastics Materials* (3-0)3
Critical examination of the new plastics appearing in the research literature and being field-tested for commercialization in the plastics industry.

26-515 Theory and Technology of Fiber Spinning* (3-0)3
Principles and theory of rheology, heat and mass transfer associated with the forming operations in melt and solution spinning of fibers. The equations of motion, continuity and energy are used to formulate the analytical description of fiber spinning. Applications of the theory are discussed in terms of equipment and practices of the synthetic fiber industry.

26-516 Composite Materials (3-0)3
Composite materials for structural applications. The behavior of constituent materials, i.e. metals, polymers and ceramics. The nature of short fiber composites are briefly examined. Methods of analyzing orthotropic lamina and laminated composites are studied. Three dimensionally reinforced composites are introducted and analyzed. Other topics include methods of fabrication, testing, joining, environmental effects and the effects of defects on the performance of composites.

26-518 Product Design (3-0)3
Theoretical principles and sound engineering practice involved in the design of new end products made from polymers, applying the total systems approach to the balance between product design, choice of materials, and processing technique, as they affect competitive choice for commercial success.

26-519 Plastics Coatings in Electronics* (3-0)3
The role of plastic coatings in electronics. Chemical, electrical, thermal, and mechanical characteristics of each major plastic family. Manufacturing technology for applying them.

26-521 Polymerization Engineering* (3-0)3
Engineering design of equipment and plants for polymer production. Processes for production of each of the major commercial polymers.

26-523 Plastics Process Design, Analysis, and Simulation (3-0)3
Calculations and simulations of batch and continuous processes. Dimensional analysis. Thermodynamic properties of thermoplastics. Enthalpy, heat capacity, sensible heat, heat of fusion, and heat of reaction. Scale-up and modelling of processes.

26-524 Process Analysis, Instrumentation, and Control* (3-0)3
Industrial instruments for measurement and control of plastics processes. Design of experiments. Analysis of plastics forming operations. Dynamic testing techniques. Automatic plastics process control. Modeling and process simulation in extrusion and injection molding. Data acquisition systems.

26-525 Processing of Fibers and Fibrous Structures* (4-0)4
An introduction to systems utilized in the processing of fiber structures. These include drawing, winding, texturing, staple fiber production, blending, static control, dyeing and finishing. The effect of these mechanical, physical, and chemical processes on the resultant fiber and fibrous structure behavior. Fibrous structures considered as reinforcements for composite materials.

26-526 Advanced Processing of Fibers and Fibrous Structures* (3-0)3
A continuation of 26-525 to include woven, knitted, nonwoven and non-conventional fibrous structures.

26-527 Mechanics of Fibrous Structures* (3-0)3
Characteristics of fibers as affecting performance of conventional and non-conventional fibrous structures. Design considerations and mechanical behavior of twisted, knitted, woven, braided, and nonwoven fibrous materials.

26-529 Evaluation of Advanced Textile Structures* (2-2)3
An introduction to the evaluation of textile structures as reinforcements for composite materials. Fibers, yarns and fabrics of carbon, boron, silicon carbide and Kevlar are considered in terms of the effects of their properties on the processing and structural behavior of composite materials.

26-532 Adhesives and Adhesion* (3-0)3
Adhesive joining of engineering materials. Surface chemistry, theories of adhesion and cohesion, joint design, surface preparation, commercial adhesives, rheology, equipment, testing, service life, and reliability.

26-533/4 Coatings Science and Technology* (3-0)(3-0)6
Polymers, pigments, solvents, and additives used in coatings. Methods of polymerization, formulation, application, and testing. Substrates and applications.

26-535 Rubber* (3-0)3
Polymerization and compounding of the commercial elastomers. Properties and test methods. Leading applications and methods of processing.

26-536 Rheology of Coatings* (3-0)3
Rheology of polymer melts, solutions, latexes and pigment dispersions, and their application to coatings and adhesives.

26-537 Engineering Properties of Plastics* (3-0)3
Theoretical basis and practical significance of the mechanical, thermal, electrical, optical, and chemical properties of plastic materials. Importance of engineering properties in material development and selection and in product design.

26-540 Commercial Development of Polymeric Material Systems* (3-0)3
The concepts of industrial marketing will be reviewed for research, pricing strategies, and product planning for market segmentation, place (distribution)-promotional activities. Topics will include creating a demand, selling, and servicing base resins and additives.

26-541 Computer Applications* (3-0)3
An introduction to microprocessor programming and interfacing. Programming includes logic operations, branch and jumps, and subroutines. Interfacing includes input and output, data acquisition systems, and controller design.

26-543/4 Survey of Plastics Materials (3-0)(3-0)6
Descriptive course centering on the historical development of polymeric systems, their synthesis, structure, properties, and applications. Included will be a brief discussion on the typical additives employed to make plastics molding compounds. Not open to B.S. Plastics Students.

26-545 Additives for Polymeric Materials* (3-0)3
Additives incorporated into polymers to modify processing and end-use properties: reinforcements, plasticizers, stabilizers, flame retardants, colorants, biostats, blowing agents, anti-stats, impact modifiers, and processing aids.

26-546 Mixing in Plastics Processing* (3-0)3
Solids mixing, mixing in viscous fluids, admixing, concept and techniques of residence time distribution, continuous and batch processes, improvement of extrudate quality, scale-up and theory of similarity, dispersion and distributive mixing, mixing and heat transfer.

26-547 Mathematical Techniques for Plastics Engineers* (3-0)3
Vector and tensor analysis, matrices and determinants, vector differential calculus, Laplace and Fourier transforms, power series, partial differential equations, introduction to numerical analysis. Use of the above techniques in plastics engineering calculations.

26-548 Numerical Techniques for Plastics Engineers* (3-0)3
Use of numerical methods in the solutions of problems concerning rheology, heat transfer, diffusion, and viscoelastic theory. Topics include solutions to ordinary differential equations, simultaneous linear equations, finite difference methods, finite element methods, plotting, linear regression, linear interpolation, curve fitting and optimization techniques.

26-549 Nylon Plastics* (3-0)3
Prerequisite: 84-223/4
Plastics applications for nylons have become extensive, and this course will trace the development of what is considered the first engineering thermoplastic. A chronological sequence from monomer synthesis to polymerization, characterization, processing, properties, and applications.

26-550 Plastics Synthesis* (3-0)3
Prerequisite: 84-223/4
A balanced treatment of all types of reactions used to synthesize plastic materials. Kinetic features of

step, chain, and ring-opening polymerizations, their scope and utility for commercial production.

26-551 Polymer Solution Systems* (3-0)3
Thermodynamics of polymer solutions. Polymer blends. Devolatilization. Diffusion and rheological properties of polymer solutions. Gel permeation chromatography and related polymer characterization methods.

26-552 Design of Polymer Processing Machinery* (3-0)3
Hydraulics, pneumatics, machine logic, drives, pumps, motors, heating and cooling, barrel and screw combinations, mechanical design, quick mold change, robots and interfacing.

26-553 Polymers in Medicine I* (3-0)3
The concepts necessary to analyze the use of materials for implants and biomedical devices will be introduced. The role of surface and bulk material properties in the use of materials in soft tissure, blood and hard tissue will be examined.

26-554 Polymers in Medicine II* (3-0)3
Prerequisite: Polymers in Medicine I
Design and test methods for polymeric based medical devices will be examined for vascular grafts, artificial hearts, reconstructive surgery, orthopedic applications, controlled release devices and hybrid artificial organs.

26-555/6 Rheology and Characterization Practicum (2-3)(2-3)6
Practical review of theoretical concepts of rheological measurements with practical applications of experimental techniques. Emphasis will be on the viscoelastic properties of polymer solutions, melts, and solids with correlation with theoretical dynamic mechanical behavior.

26-557 Composites Fabrication I* (2-2)3
Introduction to resins and reinforcements. Fabrication of thermoset composites. Hand lay-up, vacuum bagging, autoclaving, compression molding, rheological testing. Design concepts, product management, quality control.

26-558 Composites Fabrication II* (2-2)3
A continuation of 26-557 with emphasis on a semester project on design, processing, and economics of composites.

26-559 Elements of Packaging* (3-0)3
Packaging methods, materials, and container designs. Analysis of container manufacturing methods for paper, plastics, cans, cardboard and their specific properties.

26-565 Engineering Polymers (3-0)3
Prerequisite: 26-543/4
A continuation of 26-543/4 with emphasis on the engineering, high performance, and specialty polymers, including nylons, acetals, acrylics, polycarbonates, polyaryl sulfones, LCP's, polyimides,fluoropolymers, and engineering alloys/blends.

26-566 Polymeric Material Systems Selection* (3-0)3
Prerequisite: 26-201/2/301 or 26-543/4/565
This upper-level undergraduate/graduate bridge course investigates the selection processes to be followed in screening material candidates, and specifying a material of record. Emphasis is placed on prioritizing performance requirements, contrasting potential candidates, reviewing processing demands, and post-fabrication schemes. The course will be based on actual case studies.

26-571/2 Plastics Process Engineering Laboratory (0-3)(0-3)2
Laboratory study of the interaction between process variables and materials in extrusion, injection molding, blow molding, thermoforming, compounding and mixing.

26-573/4 Physical Properties Laboratory (0-3)(0-3)2
Measurement of mechanical properties in tension, compression, shear, and flexure; dielectric constant and dissipation factor; thermal behavior under stress; melt rheology.

26-577/8 Plastics Process Engineering (3-0)(3-0)6
Fundamental principles of polymer processing, the conversion of polymeric materials into useful articles. Correlation between process variables, material characteristics and part design.

26-583 Research Methodology* (3-0)3
A systematic evaluation of the techniques used in efficient research and development. Experimental data are analyzed and plotted using a mathematical approach. Creative thinking, problem solving and student presentation of data are stressed. Extensive reading of research papers, their analysis and defense of the analysis is required.

26-585/6 Computer Aided Engineering and Design* (3-0)(3-0)6
Prerequisite: 22-421
Design of plastic components and molds. Finite element programs to perform linear and nonlinear stress analysis. MOLDFLOW program for detailed mold design.

26-593 Introduction to Mold Design (2-2)3
Introduction to the fundamentals of plastics mold and die engineering. Interrelationships of polymeric materials, processing, and plastics product design; mold and die design/construction and design communications.

26-701/2 General Seminar I and II (1-0)(1-0)2
Plastics literature searching, reporting, and discussion.

26-703/4 Materials Seminar (1-0)(1-0)2
Plastics materials literature searching, reporting, and discussion.

26-705/6 Design Seminar (1-0)(1-0)2
Plastics design literature searching, reporting, and discussion.

26-707/8 Processing Seminar (1-0)(1-0)2
Plastics processing literature searching, reporting, and discussion.

26-709 Industrial Seminar (1-0)0
Visiting speakers from the plastics industry.

26-711/2/3/4 Selected Topics in Plastics (3-0)3 each
Advanced topics in the various fields of plastics. Content may vary from year to year so that students may, by repeated enrollment, acquire a broad knowledge of contemporary progress.

26-721/2/3/4 Advanced Projects in Plastics (0-3)1 each
Special projects undertaken by a student to expand his or her knowledge in specific fields not necessarily related to his or her thesis. Content of project and hours assigned must be approved by Department Chair.

26-731/2/3/4 Independent Study in Plastics (3-0)3 each
Students may study topics not offered in formal course work, under the direction of a faculty member of their choice.

26-743/6 Master's Research and Thesis (0-9)3/(0-18)6
Individual research projects in plastics.

26-753/6/9 Doctoral Research and Dissertation (0-9)3/(0-18)6/(0-27)9
Individual research projects in plastics.

* These courses are given only when there is sufficient demand.

College of Health Professions

Dean: Eleanor Forsley Shalhoup, Professor; B.S., St. Anselm's College; M.S., C.A.G.S., Ed.D., Boston University.
Assistant Dean: Susan Wozenski, A.B., Mt. Holyoke College; M.P.H., University of Michigan; J.D., University of Connecticut.

The graduate programs of the College of Health Professions in Health Services Administration, in Nursing, and in Clinical Laboratory Sciences provide specialized depth in knowledge, attitudes, and skills necessary for leadership in the health professions. The graduate program in Physical Therapy provides the student with entry level skills as a generalist in physical therapy practice.

Clinical Laboratory Sciences

Department Chairperson: Alease S. Bruce, Professor; B.S., Hampton University; M.S., Ph.D., Howard University.
Graduate Coordinator: Edward J. Weiner, Associate Professor; B.A., Northeastern University; M.A., Ph.D., Boston University.
Faculty: Kathleen Doyle, Associate Professor; B.S.M.T., University of Massachusetts; M.S., Ph.D., University of Lowell; Sandra Lee Fessia, Professor; B.S., University of Texas; M.S., Ph.D., Wayne State Medical School; Michael Frechette, Associate Professor; B.S., Merrimack College; Ph.D., University of Rhode Island; Jacob W. Lam, Professor; B.S., University of Illinois; M.S. University of Tennessee; Ph.D., University of Massachusetts, Amherst; Ted Namm, Associate Professor; B.S., M.S., Fordham University; Ph.D., University of New Hampshire; Robert J. Nicolosi, Professor; B.A., St. Anselm's College; M.S., Ph.D., University of New Hampshire; Eugene Rogers, Associate Professor; B.S., Lowell State College; M.S., Ph.D., Northeastern University; Serge Von Duvillard, Assistant Professor; Diploma, Deutshe Sporthochschule, Koln, West Germany; B.S., M.S., State University of New York at Cortland; Ph. D., University of North Texas.

Philosophy of the Department of Clinical Laboratory Sciences

The Department of Clinical Laboratory Sciences believes that every individual is entitled to quality health care, the delivery of which is in part based on continuous advancement in the clinical laboratory sciences. Dynamic technological developments in the clinical sciences have demanded a need for continuous and advanced training. In response to this demand, the Department of Clinical Laboratory Sciences believes that graduate education is necessary to prepare the laboratory professional in this rapidly changing environment.

The clinical laboratory scientist utilizes knowledge from the clinical, biological and physical sciences which may be integrated with education and administrative methodology in problem solving and the investigation of dynamic developments in the clinical laboratory. A graduate of the program is one who applies scientific theory to the application of clinical investigation and diagnosis, generates new knowledge and assumes responsibility for continuous education in order to achieve a leadership position within the profession. A graduate of the Master of Science degree program in Clinical Laboratory Sciences is an ethically responsive professional.

Program Intent

The Master of Science degree program in Clinical Laboratory Sciences provides medical technologists and individuals with medical and/or biological backgrounds with specialized knowledge in the clinical laboratory sciences. Individuals will expand their understanding of the clinical sciences and be able to apply state-of-the-art research techniques to the advancement of diagnostic technology. Knowledge of such skills will permit upward mobility into entry level supervisory positions and dissemination of clinical information in educational settings. The program integrates science components from the College of Arts and Sciences, educational components from the College of Education and management components from the Health Services Administration program in the College of Health Professions.

Program Goals

Each student upon completion of the program is expected to:

1. Integrate knowledge from specialized areas of clinical research, management and education.
2. Demonstrate competencies and advanced skills in areas of clinical specialization, research, management and education.
3. Demonstrate ability to make decisions necessary for management and supervision of a clinical laboratory.
4. Utilize teaching and management competencies to educate and supervise laboratory personnel in respective areas of specialization.
5. Demonstrate knowledge and application of research methodology.
6. Utilize research to improve the state of the art in techniques, management or education of clinical laboratory sciences.
7. Equip and manage a clinical laboratory efficiently and cost effectively.
8. Collaborate with members of other health care specialties.
9. Show evidence of continuous professional growth and leadership.

Admission Requirements

Baccalaureate degree from an accredited university or college.

Undergraduate scholastic average of 3.0 or better recommended.

Clinical certification for administration and education options.

Sound preparation in biological or clinical sciences with chemistry background for research option.

Official score report for the Graduate Record Examination Aptitude Test.

Satisfactory completion of the following option prerequisites:

Clinical Research – Clinical Biochemistry or equivalent,

Personal interview,

Three letters of recommendation pertaining to academic ability and professional performance.

Departmental Requirements

The student must have completed prior to admission or may complete without credit within the graduate program of study an introductory course in computers and a course in statistics prior to the third semester.

Degree Requirements

The Master of Science degree program in Clinical Laboratory Sciences requires the successful completion of a minimum of 38 semester hours of graduate level courses. These include 10 credit hours of core courses, 15-16 credit hours of area electives, 6-9 credit hours of free electives and 4-8 credit hours of research project or thesis. Students select their 15 credit hours of area electives from one of the areas of concentration: Clinical Research, Clinical Education or Clinical Administration.

A project which will consist of a scholarly investigation or a thesis is required for all areas of concentration. There is no formal foreign language requirement.

Core Curriculum

The core curriculum includes the following courses and must be taken by each program student:

		Credits
30-550	Human Development and Pathophysiology	3
36-555	Clinical Laboratory Management	3
33-553	Research Design and Methodology or	3
32-613	Research Methods in Planning and Evaluation	3
36-575	Seminar	1
		10

Concentration Areas

Students matriculating in the Master of Science degree program in Clinical Laboratory Sciences must select a concentration area of either: Clinical Research, Education, or Administration.

A. Clinical Research – Students selecting this concentration are expected to have either prior certification or a sound preparation in the biological sciences and chemistry.

Prescribed electives include:

		Credits
36-551	Advanced Pathophysiology	3
36-553	Advanced Clinical Biochemistry	3
36-556	Advanced Clinical Biochemistry Lab	2
		8

In addition, students select 9 semester credits from departmental course offerings or approved courses in consultation with their advisor.

B. Clinical Education

Students selecting this concentration are expected to have prior certification acceptable to the Department of Clinical Laboratory Sciences. This concentration requires the presented electives of:

		Credits
36-551	Advanced Pathophysiology	3
36-553	Advanced Clinical Biochemistry	3
36-556	Advanced Clinical Biochemistry Lab	2
		8

In addition, students take 9 semester credits from among graduate level education courses:

01-620	Theories of Learning	3
02-558	Measurement and Evaluation	3
01-621	Social Psychology in Education	3
08-657	The Role of Professional Education	3
08-659	Strategies for Instruction in Higher Education	3

C. Clinical Administration

Certification acceptable to the Department of Clinical Laboratory Sciences is required of students selecting this concentration.

Prescribed Elective

36-553	Advanced Clinical Biochemistry	3

In addition, students must take 15 semester credits from among graduate level administration courses:

32-602	Organizational Behavior in Health Care Services	3
32-614	Human Resource Management in Health Service Organizations	3
32-607	Evolution and Impact of Computers in Health Care	3
32-621	Management Information Systems	3
32-625	Health Policy	3

Electives

Two free electives may be selected from graduate offerings of the University.

Research Project or Thesis

Each student must either complete a project, an original study which integrates concepts, skills and techniques and makes a contribution to the field or a thesis; an in-depth independent investigation of contemporary clinical problems. If selecting a thesis, the student must select a committee and orally defend the work in a seminar. The thesis is subject to the guidelines and requirements of the Graduate School.

Programs of Study

Clinical Research Concentration

Semester I

30-550	Human Development and Pathophysiology	3
36-	Clinical Specialty	3
	Free Elective	3
		9

Semester II

36-551	Advanced Pathophysiology	3
33-553	Research Design & Methodology or	3
32-613	Research Methods in Planning and Evaluation	3
	Free Elective	3
36-575	Seminar	1
		10

Semester III

36-553	Advanced Clinical Biochemistry	3
36-556	Advanced Clinical Biochemistry Lab	2
36-	Clinical Specialty	3
36-743	Thesis or Free Elective	4-3
		11-12

Semester IV

36-555	Clinical Laboratory Management	3
36-	Clinical Specialty	3
36-702	Project or	
36-743	Thesis	4
		10
	Total	40-41

Clinical Education Option

Semester I

30-550	Human Development and Pathophysiology	3
01-620	Theories of Learning	3
36-	Clinical Elective	3
		9

Semester II

36-551	Advanced Pathophysiology	3
30-	Research Design and Methodology	3
01-601	Measurement and Evaluation	3
36-575	Seminar	1
		10

Semester III

36-553	Advanced Clinical Biochemistry	3
36-556	Advanced Clinical Biochemistry Lab	2
01-601	Interpersonal Relations in Education and Human Services	3
36-743	Thesis or Free Elective	4-3
		11-12

Semster IV

36-555	Clinical Laboratory Management	3
36-	Clinical Elective	3
36-702	Project or	
36-743	Thesis	4
		10
	Total	40-41

Clinical Administration Option

Semester I

30-550	Human Development and Pathophysiology	3
32-602	Organizational Behavior in Health Care Services	3
	Free Elective	3
		9

Semester II

32-607	Evolution and Impact of Computers in Health Care	3
32-625	Health Policy	3
30-	Research Design and Methodology	3
36-575	Seminar	1
		10

Semester III

32-614	Human Resource Management in Health Service Organizations	3
36-553	Advanced Clinical Biochemistry	3
36-743	Thesis or Free Elective	4-3
		9-10

Semester IV

36-555	Clinical Laboratory Management	3
32-621	Management Information Systems	3
36-702	Project or	
36-743	Thesis	4
		10
	Total	38-39

Course Descriptions

30-550 Human Development and Pathophysiology (3-0)3
Study of the physiological steady state of the human body and disruptions that result over the life span as well as the pathophysiological mechanisms manifested in disease states. Defense, compensating and adaptive responses to the pathophysiological process as they apply to the various systems are examined.

36-551 Advanced Pathophysiology (3-0)3
Prerequisite: Human Development and Pathophysiology
Disease processes as appropriate and inappropriate variants of normal physiological functions. A detailed examination of certain important and illustrative diseases rather than a survey of diseases in general.

36-553 Advanced Clinical Biochemistry (3-0)3
Prerequisite: Clinical Biochemistry
This course is designed to give an in-depth understanding in clinical chemistry. Topics include: analytical techniques and the selection of methodologies. A detailed examination of selected clinical disorders will be discussed with a biochemical viewpoint.

36-555 Clinical Laboratory Management (3-0)3
This course will introduce the student to management skills (improving communication, maintaining discipline, handling complaints), personnel relations (labor relations, interviewing, OSHA regulations), laboratory operations and state and federal regulations of the laboratory.

36-556 Advanced Clinical Biochemistry Laboratory 0-3)2
Co-requisite: Advanced Clinical Biochemistry.
Students are required to undertake individual research projects relating to topics covered in lecture.

35/36-559 Pharmacology (3-0)3
Pharmacology is an introduction to the chemistry, biochemistry and physiological actions of various pharmaceuticals. Fundamental concepts will be stressed and will include a discussion of drug receptors, drug receptor interactions, pharmacokinetics, enzyme induction, drug metabolism, drug safety and effectiveness and idiosyncratic reactions.

36-561 Topics in Pharmacology (1-0)1
Prerequisite: Pharmacology
This course emphasizes the basic principles of drug action as related to modern therapeutics. During this course each student participates in a seminar group concentrating on a specific aspect of pharmacology; this entails oral presentation of a chosen topic to the group and the writing of a paper.

35/36-563 Nutritional Biochemistry (3-0)3
This course will integrate biochemistry and physiology to gain a better perspective of how basic nutrients are metabolized during normal life-supporting processes. Subject matter will also include how abnormalities in nutrient metabolism can predispose to acute and chronic disease states.

36-575 Seminar (1-0)1
This course provides an opportunity for students to familiarize themselves with recent advances not covered in regular courses. Content varies from year to year so students may, by repeated enrollment, acquire a broad knowledge of contemporary issues. A written and oral presentation will be required as evidence of an ability to organize and evaluate published material.

36-580 Clinical and Molecular Genetics (3-0)3
This course focuses on the clinical laboratory techniques that are used in gene therapy. Modern applications of genetic engineering, data analysis, and genome sequencing technology in the clinical investigation of human disorders are covered.

36-615 Medical Parasitology (3-0)3
Prerequisite: Basic Microbiology
Study of morphology, biology, host-parasite relationship, public health problems and control of protozoa, helminths and arthropods primarily involved with parasitic diseases in man. Laboratory will introduce the most practical and reliable methods of clinical diagnosis.

36-617 Medical Mycology (3-0)3
Prerequisite: Basic Microbiology
A study of the isolation, identification, classification, epidemiology, mycoserology and clinical importance of medically significant fungi. The course will employ diagnostic methods used in the clinical laboratory including the most recent developments.

36-619 Clinical Serology (3-0)3
Prerequisite: Basic Microbiology, Basic Immunology, and Serology
Theory and procedures for identification of antibodies produced as a result of infection by microorganisms, collagen diseases and autoimmune disorders. More modern concepts of immunologic testing as immunodiffusion and fluorescent antibody will be introduced.

36-625 Erythropoeisis (3-0)3
Prerequisite: Hematology and Biochemistry
This course will provide an in-depth review of red blood cell morphology, proliferation and differentiation, as well as introduce the current clinical diagnostic procedures, correlating their results with normal and pathological states.

36-627 The Leukocytes (3-0)3
Prerequisite: Hematology and Biochemistry
An in-depth survey of both normal and pathological granulopoiesis, megakaryopoiesis, and lymphopoiesis. It will also correlate morphological and quantitative clinical diagnostic testing procedures with specific disease states.

36-629 Experimental Hematology in the Clinical Laboratory (1-0)1
Prerequisite: Hematology and Biochemistry
This course will review the current status of experimental hematology and will describe the clinical application of theoretical and technical breakthrough in the facilitation of diagnosis and evaluation of hematological disease states.

36-361 Advanced Clinical Hematology Seminar (1-0)1
Prerequisite: Hematology, Biochemistry or permission of the instructor
This course will review selected theoretical and technical topics in the field of clinical hematology. Students will prepare detailed seminars describing current research, clinical case studies, as well as specific problems facing the clinical laboratory scientist.

36-633 Topics in Coagulation (1-0)1
Prerequisite: Hematology, Biochemistry or permission of instructor.
A review of all physiological, molecular, and technical aspects of hemostasis. Students will take part in describing the current problems, as well as the on-going research taking place to further the understanding of both the normal and pathological blood clotting states.

36-657 Clinical Toxicology (3-0)3
Prerequisite: Pharmacology and Biochemistry
Designed to examine the instrumental methods of assay. Toxicologic and pharmacologic action on and by the host organism will be described. Major drugs and toxin types will be reviewed.

36-659 Advanced Instrumentation (3-0)3
A study of current principles of automated analysis as applied to the clinical laboratory. The course will provide practical exposure to several commercially available systems.

36-661 Medicinal Chemistry (3-0)3
Prerequisite: Pharmacology, Biochemistry, and Organic Chemistry.
A study of the basic underlying chemical principles which account for the properties of drugs and an understanding of drug action. The principles relating biologic activity or molecular structure will be discussed.

36-663 Topics in Medicinal Chemistry (1-0)1
Prerequisite: Medicinal chemistry or permisson of instructor
Course will emphasize special areas of medicinal chemistry such as steroids, CNS compounds, pharmacodynamic agents and chemotherapeutics.

36-702 Research Project in Clinical Laboratory Sciences (0-9)4
Prerequisite: Written permission from Graduate Coordinator
Prerequisite: Research Design and Methodology
An independent study or laboratory project which has been approved and is under the direction of the project advisor. Projects are approved by the graduate coordinator in conjunction with the project advisor.

36-743 Thesis I (0-9)4
Prerequisite: Research Design and Methodology
Analytical and/or experimental work conducted under the direction of a thesis advisor and in accordance to the Graduate School Guidelines. Students are required to submit a written proposal for approval by a thesis committee and to present an oral defense at a college seminar.

36-746 Thesis II (0-9)4
Prerequisite: Thesis I
The investigation proposed in Thesis I implemented with, and culminating in, an approved written report in thesis form.

Health Services Administration

Department Chairperson: Karen M. Lorentzen, Professor; B.S., Adelphi University; M.S., St. John's University; Ed.D., Boston University.
Graduate Coordinator: Vincent Pivnicny, Assistant Professor; B.A., Lafayette College; M.S., Boston University; Ph.D., University of Pittsburgh.
Faculty: Beverly J. Volicer, Professor; A.B., University of Iowa; M.A., M.P.H., Ph.D., University of Michigan.

Master of Science Degree Program in Health Services Administration

Philosophy of the Department of Health

The faculty of the Department of Health believes that each individual is a unique rational human being who must have the opportunity to interact effectively within a changing environment. Individuals possess innate rights, one of which is the attainment of the goal of optimal health. Society, through its community and educational institutions, has a responsibility to make available for its citizens the methods and means for achieving the goals for an optimal level of health. To this end the Department of Health is committed to prepare professional practitioners who, from their own health practice discipline, assist the individual, the family, the group and the community to achieve as high a level of health as possible.

Program Intent

The goal of the graduate program in Health Services Administration is to provide health services administrators with the specialized knowledge and skills necessary to administer the delivery of high quality and cost effective health services and health promotion programs.

The core curriculum is designed to foster the ability to make administrative decisions based on sound management principles and scientific methods. Each student selects one of two options for additional specialized work in either Health Care Management or Health Promotion Management. The computer skills necessary for modern health care and health promotion management are integrated throughout the curriculum.

The program is designed to accommodate individuals already employed in the health care field who wish to further their professional training, and for college graduates preparing to enter the field. Course requirements may be completed on either a full-time or part-time basis.

Admission Requirements

Requirements include a baccalaureate degree from an accredited institution with an undergraduate scholastic average of 3.0 or better and an acceptable score on the Graduate Management Admission Test (GMAT) or the Graduate Record Examination Aptitude Test (GRE). Applicants whose degree is from foreign institutions must have it validated by the Center for Educational Documentation, P. O. Box 326, Boston, MA 02130 or a similar agency. Three letters of recommendation pertaining to academic ability and professional performance must be submitted. A personal interview may be requested by the departmental faculty. Evidence of satisfactory completion of a prerequisite statistics course must be submitted. Background in accounting or a basic health science course may be required as prerequisites for specific courses in the program.

Program Requirements

1. **Credits**
   Forty-eight credit hours of course work will be required of all students enrolled in the program. There are no formal language or comprehensive examination requirements. Completion of a thesis or a project is required for graduation.
2. **Program of Studies**
   The Master of Science in Health Services Administration consists of 48 credits as follows:

9 Core Courses	27
3 Specialized Courses	9
1 Elective	3
Internship	6
Project or Thesis	3
	48

Core Courses (9 courses - 27 credits)
These courses must be taken by every student in the program:

32-602 Organizational Behavior in Health Care Services
32-604 Principles of Epidemiology
32-606 Quantitative Methods for Health Services
32-607 Health Care Information Systems
32-611 Health Care Finance*
32-613 Research Methods
32-614 Health Care Management
32-626 Program Development and Evaluation
32-627 Planning and Marketing for Health Care Services

* An optional 1-credit course, Health Care Accounting, 32-661 runs concurrently with 32-611

Courses required for option (students take all 3 courses in 1 area - 9 credits)

Courses for Health Care Management Option
32-612 Operations Analysis and Control
32-615 Health Care Financial Management
32-625 Health Policy

Courses required for Health Promotion Management Option
32-631 Educational Foundations for Health Promotion
32-632 Epidemiological Basis for Health Promotion
32-633 Applied Studies in Health Promotion

Departmental Electives (students select 1 course - 3 credits)
32-616 Health Law
32-621 Management Information Systems
32-628 Ethics in Health

All students must also complete the following courses (9 credits):
32-617 Internship and Seminar
32-743 Project or Thesis

Health Services Administration Program Expected Outcomes

Upon completion of the program, each student is expected to:

Integrate knowledge from the fields of health services and health systems, management, health, and the behavioral sciences to identify analyze, and address problems.

Apply theory to the administration of health care.

Demonstrate specialized administrative competencies including advanced skills in the functions of planning, organizing, controlling and evaluating health care and health promotion.

Analyze legal, fiscal, regulatory and environmental factors influencing health care and health promotion.

Demonstrate the ability to make effective administrative decisions.

Communicate effectively.

Demonstrate knowledge of research methodology.

Utilize research to improve practice and expand knowledge in health services administration.

Demonstrate basic competency in the financing of health care.

Course Descriptions

32-602 Organizational Behavior in Health Care Organizations (3-0)3
Applies social science theory to health care organizations. Overview of the health care system and examination of roles of key actors. Emphasis on use by students of course material to analyze change in health care organizations.

32-604 Principles of Epidemiology (3-0)3
Basic concepts of epidemiological reasoning in context of current trends in major health problems. Emphasis on interpretation of epidemiological data and application of epidemiological information to management of health care and health promotion.

32-606 Quantitative Methods for Health Services (3-0)3
Prerequisite: a statistics course.
Application of bivariate and multivariate biostatistical methods to problems in health care management and health promotion. Emphasis on 1) determinants of appropriate procedures, 2) utilization of computer software for analysis, 3) and interpretation of statistical results.

32-607 Health Care Information Systems (3-0)3
Introduces computer applications and management issues in health care. Overview of hardware and software products. Management issues attendant to the design and implementation of computerized systems. Alternative strategies considered and presented.

32-611 Health Care Finance (3-0)3
Presents important macreoeconomic aspects of health care economics at the state and local level and describes their effects on health care providers. Instruction in operating, capital and cash budgeting. Foundation in basic tools of financial analysis.

32-612 Operations Analysis and Control (3-0)3
Fundamentals of analysis and control of internal operations used in managing health care. Uses spreadsheet. Includes operations functions, design of systems, capacity utilization, quality control and inventory management.

32-613 Research Methods (3-0)3
Development of knowledge and skills useful for research in health services, ethical and political issues. Topics include study design, measurement, data collection and analysis and interpretation of findings. Applications to program management.

32-614 Health Care Management (3-0)3
Provides framework for addressing management principles and activities in health care organizations. Examines management functions, processes and issues and the internal and external environments. Students apply managerial principles to health care delivery systems.

32-615 Health Care Financial Management (3-0)3
Prerequisite: an elementary accounting course or permission of instructor and 32-611.
Tools and techniques necessary to manage the financial resources of health care organizations, report financial results, formulate strategic financial plans, and assess the fiscal impacts. Covers financial statements, cost accounting and analysis; and strategic planning methods.

32-616 Legal Issues in Health Services Administration (3-0)3
Exposes the student to those legal concepts, principles and issues germane to the administration of various health care delivery systems which comprise the American health services model.

32-617 Internship and Seminar (0-9)3
Provides an opportunity to work in health services administration under a qualified preceptor. Seminars with faculty integrate this experience with academic training. Placement decisions are made by faculty on the basis of student interests, needs, and abilities.

32-621 Management Information Systems (3-0)3
Prerequisite: 32-607 or an elementary computer or information systems course.
Overview of major types of M.I.S. applications in health care settings. Review of components of M.I.S. and trends in software. Current issues in design of control systems both for administration of institutions and for managing patterns of patient care.

32-625 Health Policy (3-0)3
Provides students with a framework for policy analysis and examines major strands of U.S. health policy. Detailed consideration and discussion of the relationship of national policy to the planning, implementation and funding of health care services.

32-626 Program Development and Evaluation (3-0)3
Development, monitoring and evaluation of health care programs. Includes problem identification, formulation of goals and objectives, financing and resource availability, budgeting, monitoring and control, and evaluation strategies and methodologies.

32-627 Planning and Marketing for Health Care Services (3-0)3
The history, principles and methodologies of health services strategic planning and marketing are examined. Relevant primary and secondary sources of information are identified. Functions of board, management and planner/marketer are explored.

32-631 Educational Foundations for Health Promotion (3-0)3
Examines educational strategies for effective community and school promotion programs. Focus on the application of educational principles, including behavioral change.

32-632 Epidemiological Basis for Health Promotion (3-0)3
Prerequisite, a basic health sciences course or permission of instructor and 32-604.
Examination of major epidemiological studies identifying risk factors for leading causes of death and disability in the U.S. Reviews epidemiological basis for health promotion programs such as maternal and child health, infectious diseases and AIDS.

32-633 Applied Studies in Health Promotion (3-0)3
Prerequisite, 32-631 and 32-632.
Analysis of model health promotion programs designed to reduce morbidity and mortality due to major health problems such as heart disease, cancer and stroke. Derivation of principles useful in the development of new programs.

32-661 Health Care Accounting (1-0)1
Provides an introduction to accounting for health administrators. Runs concurrently with 32-611, Health Care Finance, but is not required for students in Health Services Administration.

32-743 Project or Thesis (3-0)3
Each student is required to complete a thesis or project under the supervision of a faculty member. The project is intended to integrate the concepts and skills learned in previous courses, should be original, and make a contribution to the field. Theses must meet the requirements of the Graduate School.

Department of Nursing

Department Chairperson: Janice Stecchi, Professor; B.S., Boston College; M.Ed., Salem State College; M.S., Ed.D., Boston University.
Graduate Coordinator: May Futrell, Professor; B.S., M.A., Columbia University; Certificate, University of Southern California; Ph.D., Brandeis University.
Faculty: Frances Bushnell, Assistant Professor; B.S.N., University of New Mexico; M.S.N., M.P.H., Yale University; Ed.D; Boston University; Nina M. Coppens, Associate Professor; B.S., M.S., Northern Illinois University; Ph.D., University of New Hampshire; Cheryl Lorane Cox, Professor; B.S.N., University of Tennessee; M.S. N., Vanderbilt University; Ph.D., University of Rochester; Janet Douglass, Associate Professor; B.S., St. Anselm's College; M.S., Boston College; D.N.Sc., Boston University; Marian D. Dubrule, Associate Professor; B.S., Iowa State University; M.N., Yale University; M.Ed., M.S., Ed.D., Boston University; Sharon George, Instructor; B.S., Northeastern University; M.S., University of Lowell; Joan Lewis, Associate Professor; B.S., Ed.M., Boston College; Ed.D., Boston University; Karen Devereaux Melillo, Assistant Professor; B.S., Salem State College; M.S., University of Lowell; Susan Reece, Assistant Professor; B.S., Russell Sage College; M.S., Boston College; D.N.Sc., Boston University; Eleanor Forsley Shalhoup, Professor and Dean

of the College of Health Professions; B.S., St. Anselm's College; M.S., C.A.G.S., Ed.D., Boston University; Grace Sullivan, Assistant Professor; B.S. Lowell State College; M.S., University of Lowell; D.N.Sc., Boston University; Patricia Tyra, Associate Professor; B.S., M.S., Ed.D., Boston University; Eileen Williamson, Associate Professor; B.S. Lowell State College; M.S., D.N.Sc., Boston University.

Philosophy

Humans are unique, sentient and rational beings endowed with individual qualities and have basic needs for respect, worth, and recognition of personal dignity. Humans are continually adapting by developing and interacting, individually or in groups, with a changing multidimensional environment. Humans have the right and ability to make choices and establish goals which influence and are influenced by culture, beliefs, others, the environment and present health state.

Health is a dynamic state of physiological, psychological, social and spiritual well-being and not merely the absence of disease. Individuals manifest health on a wellness continuum and have potential for multidimensional movement.

The environment is the sum total of factors that make up the surroundings and influence adaptation. Dynamic relationships with the environment both enable and limit the development and health of individuals, families and communities. Health care is a right, and an individual's option to choose participation in the process of health care delivery must be respected.

Professional nursing is an academic and practice oriented discipline with the responsibility to develop and refine its knowledge base through continuing scientific inquiry and analysis of existing theories. Nursing practice supports human growth and adaptation by assisting individuals, families, groups and communities in the development of strategies that promote health. Through the application of the nursing process, the professional nurse formulates interventions that are scientific, rational, deliberate and humanistic. Nursing actions are goal-oriented and based on scientific knowlege and research findings.

Baccalaureate nursing education incorporates liberal education with generalized preparation in professional nursing. The professional nurse is prepared at the baccalaureate level in nursing to give direct care and function in collaborative relationships with other professionals in a variety of settings to deal with diversified health concerns of individuals, families, and communities.

Graduate nursing education, predicated upon a generalist preparation, prepares leaders capable of improving nursing care, advancing nursing science, and initiating change in the health care system. The master's prepared nurse improves the quality of care through advanced knowledge, clinical judgement, valuing, scientific inquiry, humanistic endeavors and evaluation.

The faculty recognizes that each student is unique and brings to the educational environment a variety of life experiences. Individual interests and goals are recognized as an important compliment of the educational process. Faculty assumes responsibility for the overall structuring of the educational environment which allows for discovery, transmission, and integration of knowledge and the acquisition of skills to achieve personal and professional goals. Teacher and learner participate in the educational process through planning educationally sound and growth-promoting experiences and sharing knowledge. Support of the individual's growth and self-evaluation during the educational process enables the student to develop his or her career. The faculty believes that education is a self-actualizing, creative, lifetime endeavor which involves values clarification, progressive systematic inquiry, critical analysis and judgement. Advanced preparation at the master's and doctoral level is a means by which personal and professional goals can be actualized.

Program of Study

The curriculum leading to a Master of Science degree with a major in Nursing emphasizes depth of knowledge and excellence in nursing in three areas of specialization: Administration of Nursing Services, Gerontological Nursing and Family and Community Health Nursing.

The major purposes of the Master of Science program are to: 1) provide advanced educational opportunities in nursing for baccalaureate prepared nurses; 2) prepare leaders in Gerontological Nursing, Family and Community Health Nursing, and Administration of Nursing Services capable of improving nursing care through the advancement of nursing theory and science; 3) prepare leaders capable of planning and initiating change in the health care system; 4) provide a basis for doctoral education.

The graduate program is designed for a four-semester, two-calendar year schedule, although part-time study is possible. Within each major area of specialization all students are prepared with knowledge and skills necessary for leadership in a variety of settings. Methods of inquiry, research and scholarly techniques are integral parts of the curriculum.

Program Objectives

The master's degree program prepares graduates who are able to:

1. demonstrate, through advanced nursing practice a philosophy of nursing based on values that support the intrinsic worth and dignity of each individual;
2. actively engage in effective collegial relationships with peers and other health professionals to improve health care and health care services;
3. demonstrate advanced clinical expertise in a specialty;
4. evaluate their own practice and promote professional and ethical standards of advanced professional practice in a specialty;
5. apply relevant theories and research findings in nursing practice to promote optimum wellness and to advance nursing;
6. initiate change for the improvement of health and health care services through consultation, collaboration, advocacy, and accountability;
7. evaluate changes and the change process for the improvement of health and health services;
8. evaluate social, political, legal and ethical issues affecting nursing in an area of specialization and develop strategies for effective role implementation;
9. conduct scientific inquiry to contribute to knowledge relevant to nursing; and
10. promote personal and professional development by continuing to acquire knowledge relevent to a specialized role.

Admission Requirements

Although each applicant is considered on an individual basis, admission requirements are as follows:

1. official proof of receipt of a baccalaureate degree with a major in Nursing from a National League for Nursing-accredited school,
2. minimum undergraduate grade point average of 3.0 (B),
3. satisfactory completion of an introductory course in descriptive and inferential statistics,
4. Massachusetts registered nurse licensure,
5. three letters of reference,
6. pre-admission interview, and
7. official score report of the Graduate Record Examination Aptitude Test.

Additional Information

Students must carry malpractice insurance. Evidence of such must be presented at the time of registration.

Entering students are required to submit proof of the following to the University Health Service prior to registration:

1. immunization for measles and mumps, tetanus and diphtheria;
2. either a rubella titer of 8 or greater or immunization for rubella,
3. a T.B. Mantoux test, and
4. evidence of having received at least three doses of trivalent oral polio vaccine. A

booster dose is recommended for students who received three or more doses in early childhood.

5. The results of a physical examination must be submitted, using the University form obtained from the University Health Service office.

Degree Requirements

A minimum of 42 credits of course work will be required of all students. There are no formal language or comprehensive examination requirements. A research project or a thesis is required for graduation.

Part-Time Study

Students may be admitted for part-time study. Part-time students must meet the same admission requirements for graduate study as full-time students. Part-time students will meet with their assigned advisor and plan a schedule for their program of studies. This program of studies is planned by the end of the first semester so that placement in clinical nursing courses can be assured. Enrolling in courses as scheduled or changing courses requires approval from students' advisors. Students planning to complete the total program on a part-time basis may face delays if they decide to change to full-time status after admission.

Curriculum

All students take the following core courses:

33-600 Theoretical Foundations for Advanced Nursing Practice
33-553 Research Design and Methodology
33-615 Independent Study - Research

Gerontological Nursing and Family and Community Health Nursing Students take the following courses:

33-651 Nurse Practitioner Role – Theory and Practice
30-550 Human Development and Pathophysiology

Areas of Specialization

Administration of Nursing Services

The ultimate goal of nursing services is improvement of the human condition. The curriculum is designed to prepare nurses for effective administration of nursing services within the health care system.

The following courses are required for Administration of Nursing Services:

33-680 Concepts and Theories of Nursing Administration
32-602 Organizational Behavior in Health Care Services
33-554 Selected Topics in Human Resource Management
33-681 Nursing Administration I
33-682 Nursing Administration Practicum I
32-611 Health Care Finance
33-613 Health Care Finance Seminar
33-683 Nursing Administration II
33-684 Nursing Administration Practicum II
33-685 Nursing Administration III
2 Electives

Gerontological Nursing

This specialty focuses on facilitating the health practices of older adults during the process of normal aging and identifying common health problems. Students develop advanced skills in communicating with older adults, health assessment, health teaching and nursing intervention and evaluation. Students are prepared as nurse practitioners and eligible to sit for the gerontological and adult nurse practitioner certification exams.

The following courses are required:

33-610 Gerontological Nursing I
33-613 Gerontological Nursing Practicum I
33-611 Gerontological Nursing II
33-614 Gerontological Nursing Practicum II
47-551 Psychosocial Aspects of Aging
33-612 Gerontological Nursing III
2 Electives

Family and Community Health Nursing

This specialty focuses on facilitating the health practices of families during the process of normal development and identifying common health problems across the life span. Students develop advanced skills in communicating with families, health assessment, health teaching and nursing intervention and evaluation. Students are prepared as nurse practitioners and are eligible to sit for the family nurse practitioner certification exam.

The following courses are required:

33-660 Family and Community Health Nursing I
33-663 Family and Community Health Nursing Practicum I
33-661 Family and Community Health Nursing II
33-664 Family and Community Health Nursing Practicum II
47-504 The Family System
33-662 Family and Community Health Nursing III
2 Electives

Doctor of Nursing Science

A proposal for a Doctor of Nursing Science (D.N.Sc.) degree has been accepted for planning by the Massachusetts Board of Regents of Higher Education. The Department of Nursing is actively plannng and developing the curriculum for final approval by the Board of Regents.

Course Descriptions

30-550 Human Development and Pathophysiology (3-0)3
Study of the biological aging process and its effect on the various physiological parameters of wellness. Defensive, compensatory, and adaptive responses to pathophysiologic processes are examined.

33-553 Research Design and Methodology (3-0)3
Study of the research process and the application of appropriate designs and methodologies in the investigation of health care problems.

33-600 Theoretical Foundations for Advanced Nursing Practice (3-0)3
Study of selected nursing theories and assumptions about person, health, environment and nursing. Concepts, theoretical structures, theory development and evolution and their relationship to nursing are examined.

33-651 Nurse Practitioner Role – Theory and Practice (2-4)3
Analysis and conceptualization of the nurse practitioner role in health care delivery systems.

33-680 Concepts and Theories of Nursing Administration (3-0)3
Focus on the organization of nursing administration systems within complex health care systems.

33-681 Nursing Administration I – Nursing Management within Organizations (3-0)3
Study of existing models for delivery of nursing services in a variety of organizational structures. Development of a model for administration of nursing services is emphasized.

33-554 Selected Topics In Human Resource Management (3-0)3
Information systems, behavioral systems and process systems will be considered in the context of role development of the human resource manager.

33-682 Nursing Administration Practicum I (0-4)1
Observation and experience in a health care setting. Analysis of organizational behavior based on nursing and management theories.

33-683 Nursing Administration II – Functional Role of the Nurse Administrator (3-0)3
The use of theory to explain roles and functions in nursing administration. Decision-making, budget preparation, time management, advocacy, quality assurance and ethical/legal issues are included.

33-684 Nursing Administration Practicum II (0-4)1
Experience in a nursing care setting to analyze selected nurse management functions. Focus on problem-solving in nursing management using the conceptual models.

33-685 Nursing Administration III (1-12)4
A practicum in administration of nursing services. Weekly seminars provide the student with the opportunity to synthesize the knowledge and skills from prior courses.

33-610 Gerontological Nursing I (4-0)4
Study of older adults and examination of commonly occurring health problems, family and community resources, legislative influences and ethical considerations. Emphasis placed on values, concepts and theories relative to the well-being of the aged individual.

33-613 Gerontological Nursing Practicum I (0-12)3
Development of leadership role in gerontological nursing. Focus is on comprehensive assessment, clinical decision making, identification of health problems and advanced nursing strategies to facilitate health promotion and maintenance.

33-611 Gerontological Nursing II (4-0)4
In-depth analysis of physiological and psychosocial factors relative to promoting, maintaining and restoring health of older adults.

33-614 Gerontological Nursing Practicum II (0-12)3
Practice in a leadership role in gerontological nursing. Emphasis on comprehensive assessment, advanced clinical decision making and management of acute and chronic stable conditions of the older adult. Opportunity to apply and evaluate concepts, theories and research findings are provided.

33-612 Gerontological Nursing III (1-12)4
Synthesis of advanced knowledge and research serve as the basis for advanced gerontological nursing practice. Emphasis on implementation and evaluation of advanced practice strategies and the leadership role of the gerontological nurse practitioner.

33-660 Family & Community Health Nursing I (4-0)4
Study of families with infants and children from multi-cultural systems, and examination of commonly occurring health problems. Emphasis placed on values, concepts and theories in terms of facilitating health promotion, maintenance and restoration.

33-663 Family & Community Health Nursing Practicum I (0-12)3
Focus on development of leadership role in family health nursing. Emphasis placed on comprehensive assessment, clinical decision making, identification of health problems and advanced nursing strategies to facilitate health promotion and maintenance.

33-661 Family & Community Health Nursing II (4-0)4
Analysis of biological and psychosocial factors related to the health of childbearing, middle-aged and older adults within family systems and community suprasystems. Acute and chronic health problems are explored in depth.

33-664 Family & Community Health Nursing Practicum II (0-12)3
Practice in a leadership role in family health nursing. Emphasis on comprehensive assessment, advanced clinical decision making and management of acute and chronic health conditions. Opportunity to apply and evaluate concepts, theories and research findings are provided.

33-662 Family & Community Health Nursing III (1-12)4
Synthesis of advanced knowledge and research serve as the basis for advanced family nursing practice strategies. Emphasis on implementation and evaluation of advanced family practice strategies and the leadership role of the family and community health nurse practitioner.

33-743 Research (3-0)3
Application of research design and methodology culminating in the completion of a master's project or thesis under the guidance and supervision of the faculty.

Department of Physical Therapy

Department Chairperson and Graduate Coordinator: Joseph A. Dorsey, Professor, B.S., Springfield College, M.Ed., Northeastern University, C.A.G.S., New York University, Ed.D., Boston University.
Faculty: Barbara Cocanour, Associate Professor; A.B., The Defiance College, M.S., Ph.D, University of Maine; Linda Kahn-D'Angelo, Associate Professor; B.A., Merrimack College, M.A., Texas Women's University, Sc.D., Boston University; Roberta Mawdsley, Associate Professor; B.S., Springfield College; Certificate in Physical Therapy, U.S. Army Medical Field; M.Ed., Boston College; Ed.D., Boston University; Susan O'Sullivan, Assistant Professor; B.S., M.S., Ed.D., Boston University; Nancy Peatman, Academic Coordinator of Clinical Education; B.S., University of Connecticut, M.Ed., Fitchburg State College; Joyce White, Assistant Professor; B.S. University of Connecticut, M.S., Boston University.

Philosophy

The faculty of the Department of Physical Therapy believes that individuals have intrinsic worth and a right to optimal health which enables them to interact effectively in a changing environment. To this end, members of society are responsible for taking an active and cooperative role in personal health and maintenance. When physical, biological, psychological or social changes occur they may cause deficits in effective functioning. Physical therapy is integral to the prevention of disability caused by these changes as well as to the maintenance or rehabilitation of individuals to their optimal level of functioning.

The physical therapist is prepared in an academic program which synthesizes undergraduate background with graduate study that integrates professional physical therapy knowledge, theory and psychomotor skills. The graduate of the Department of Physical Therapy is an ethical and competent professional who uses the problem solving approach and research process for clinical practice, teaching, management, consulting and advocacy. Commitment to life long learning is the basis for continued personal and profes-sional growth.

The faculty believe that students are active participants in the educational process. As potential professionals, the relationship between students and faculty is one in which there is mutual respect, understanding and interchange of ideas. Faculty, as experienced professionals, are resource persons, counselors, facilitators, motivators and role models for the potential professional. Students are self-directed, commited and motivated.

Graduates are prepared to assume a leadership role in health care by practicing autonomously and cooperatively in a variety of settings such as: hospitals, rehabilitation centers, schools, extended care facilities, industry, sports medicine, community health and private practices.

Program of Study

The Department of Physical Therapy at the University of Lowell offers an entry level graduate curriculum of three components: cardiopulmonary, neurological and musculoskeletal physical therapy concepts, techniques, and skills. The course of study is designed to synthesize graduate study, undergraduate knowledge, and experiential learning to prepare graduates to be general practitioners of physical therapy with the capability to fulfill their roles as researchers, educators and consultants.

The graduate degree requires a two and one-half year program of study, during which students participate in a variety of clinical experiences.

Program Objectives

The graduate of the Master of Science degree program in Physical Therapy at the University of Lowell will be prepared to:

1. Maintain respect for human dignity in interaction with others.
2. Promote the prevention of disability, the rehabilitation to and the maintenance of optimal function through the practice of physical therapy.
3. Synthesize the knowledge of the pure and applied sciences, sociology, psychology and human values with the knowledge, theory and psychomotor skills of physical therapy.
4. Evaluate the physical therapy needs of individuals of all ages using the problem-solving approach.
5. Implement a physical therapy plan of care based on identified needs.
6. Communicate effectively with colleagues, clients and families.
7. Utilize psychomotor and affective skills in the treatment of clients.
8. Practice physical therapy in a safe, effective, ethical and legal manner in a variety of health care settings.
9. Coordinate the results of pertinent research reported in the literature in the delivery of physical therapy services.
10. Advance the theory and practice of physical therapy through research.
11. Integrate teaching and learning principles in all facets of physical therapy practice.
12. Promote and facilitate necessary change within the health care delivery systems to assure quality health care.

13. Facilitate the practice of health promotion and disease prevention.
14. Practice autonomously in a leadership role in a variety of clinical settings as a facilitator, counselor and motivator.
15. Utilize principles of formal organization, organizational behavior and management in the delivery of physical therapy services.
16. Collaborate with health practitioners, consumers, and governmental agencies to provide cost effective health care of high quality.
17. Demonstrate a commitment to personal and professional development.
18. Adhere to the code of ethics promulgated by the American Physical Therapy Association.

Admission Requirements

1. Baccalaureate degree from an accredited college or university.
2. Minimum undergraduate average of 3.0.
3. Acceptable scores on the Graduate Record Examination Aptitude Test.
4. Personal experience in a physical therapy setting as a volunteer or employee.
5. Personal interview with the Department and three letters of recommendation.
6. Successful completion of all prerequisite courses.

Additional Requirements

1. Students are responsible for carrying malpractice insurance.
2. Proof of immunization acquired within six months prior to admission for measles, mumps, rubella, tetanus, polio, diptheria and tuberculosis is required.
3. Applicants must provide a report of a physical examination by a physician conducted within six months prior to admission indicating present general health status.
4. The clinical education component of the curriculum is directed by the academic coordinator of clinical education in collaboration with physical therapy faculty. It includes three full-time clinical education experiences of six, eight and eight weeks respectively. These full-time experiences occur in the summer following the first year of study and in the summer and fall following the second year. They are provided in collaboration with a variety of health care facilities throughout the United States.

An integrated experience of one week duration is scheduled in each academic semester beginning in the spring of the first year. These short term experiences will occur in a variety of clinical facilities within New England.

Physical therapy students are responsible for all costs related to clinical education including transportation, housing, meals and tuition/fees. Students should expect and plan for out-of-state clinical placements. Students are expected to dress in a professional manner while on integrated and full-time clinical assignments.

General prerequisites should include:

Humanities
- 6 credits English composition
- 3 credits literature
- 6 additional credits

Social and Behavioral Science
- 9 credits of psychology
- 3 credits developmental
- 3 credits interpersonal relationships
- 3 additional credits
- 3 credits sociology

Biological Science
- 8 credits anatomy & physiology with labs

Chemistry
- 4 credits general with lab
- 4 credits organic with lab

Physics
- 8 credits with labs

Statistics
- 3 credits

Computer Science
- 3 credits

Professional Prerequisites

Pharmacology
- 3 credits

Kinesiology
- 4 credits with lab

Exercise Physiology
- 4 credits with lab

Students may be asked to provide documentation of the content of courses taken to meet admission criteria.

Course of Study

Year One

Fall

34.601	Clinical Anatomy	3
34.603	Clinical Anatomy Lab	1
34.605	Basic PT Procedures Lecture	3
34.607	Basic PT Procedures Lab	1
34.609	Medical/Surgical Conditions	3
34.611	Ethics and Professional Issues in Physical Therapy	3
34.613	Principles of Clinical Teaching	3
		17

Spring

34.602	Neuroscience: Anatomy	3
34.604	Neuroscience: Physiology/ Neurology	3
34.606	Neuroscience Lab	1
34.608	Musculoskeletal PT I Lecture	3
34.610	Musculoskeletal PT I Lab	1
34.612	Cardiopulmonary PT Lecture	3
34.614	Cardiopulmonary PT Lab	1
34.616	Research Methods	3
		18

Integrated Clinical Experience (1 week)

Summer

34.615 Clinical Education Experience I (6 weeks, 2 credits)

Year Two

Fall

34.617	Neurological PT I Lecture	3
34.619	Neurological PT I Lab	1
34.621	Musculoskeletal PT II Lecture	3
34.623	Musculoskeletal PT II Lab	1
34.625	Electrophysiology Procedures	3
34.627	Electrophysiology Procedures Lab	1
34.629	Research Seminar	2
34.631	Pediatric PT Lecture	3
34.633	Pediatric PT Lab	1
		18

Integrated Clinical Experience (1 week)

Spring

34.618	Management	3
34.620	Neurological PT II Lecture	3
34.622	Neurological PT II Lab	1
34.624	Directed Research/Clinical Integration Seminar	3
34.626	Geriatric PT	3
34.628	Musculoskeletal PT III Lecture	3
34.630	Musculoskeletal PT III Lab	1
		17

Integrated Clinical Experience (1 week)

Summer/Fall

34.634 Clinical Education Experiences II
34.635 Clinical Education Experiences III (16 weeks, 4 credits)

76 semester hours to complete program

Course Descriptions

34.601 Advanced Anatomy (3-0)3
Advanced Anatomy is a study of the structures of the human body, utilizing lectures, demonstrations and audiovisual materials.

34.602 Neuroscience: Anatomy (3-0)3
This course presents the structural features of the central nervous system as they relate to problems encountered in clinical neurology.

34.603 Clinical Anatomy Laboratory (0-3)1
Advanced anatomy laboratory is a visualization of the structures of the human body utilizing laboratory dissection of prosected parts and human cadavers. The laboratory also incorporates the recognition of underlying structures using surface anatomy and palpation of bony and soft tissues.

34.604 Neuroscience: Physiology and Neurology (3-0)3
Neuroscience presents the principles of neurophysiology, neurology, and motor control as

related to the practice of physical therapy. Topics in neurophysiology include: conduction and transmission of the nerve impulse, neuromuscular synaptic transmission and skeletal muscle contraction, muscle tone and spinal reflexes, the neurophysiology of sensation and movement, and the transmission of pain. Neurological conditions will be integrated with these various neurophysiological topics through the use of case studies and will include: peripheral nerve injuries, neuromuscular conditions, and diseases/conditions of the central nervous system. An introduction to the major theories of motor control and their application to physical therapy evaluation and treatment will be discussed through problem solving and case studies.

34.605 Basic Physical Therapy Procedures Lecture (3-0)3
This course introduces students to the principles of patient evaluation and treatment utilizing the problem solving framework of the problem oriented medical record system. The purpose and appropriate use of evaluation procedures and the rationale for safe and effective use of treatment procedures are emphasized. Topics include: organ-ization of patient records, patient interviewing, isolation/sterile techniques, monitoring of vital signs, body mechanics, patient positioning, transfers, gait training and activities of daily living with assistive devices, wheelchair prescription and mobility, heat and cold modalities, and hydrotherapy.

34.606 Neuroscience Laboratory (0-3)1
Neuroscience laboratory includes study of the anatomy and function of the human brain, spinal cord, peripheral and autonomic nervous systems through prosection, audiovisual resources and experimental procedures. The gross anatomy of the human brain and spinal cord will be visualized using prosections of human specimens, models, and slides. Experimental procedures include electromyographic recording of muscle action potentials, evaluation of reflex function in normals, assessment of sensory and cerebellar mechanisms, and testing cranial nerve function. In order to synthesize this course content each student will present a neuropathology case study.

34.607 Basic Physical Therapy Procedures Laboratory (0-3)1
This laboratory course develops psychomotor skills to allow clinical application of didactive knowledge gained in Basic Physical Therapy Procedures Lecture. The safe and effective performance of various evaluation and treatment techniques are emphasized along with appropriate and effective communication skills. Topics include: patient interviewing; isolation/sterile techniques; monitoring vital signs, patient positioning and bed mobility; transfers, gait training and activities of daily living with assistive devices; wheelchair mobility; massage techniques, cold and heat modalities, hydrotherapy.

34.608 Musculoskeletal Physical Therapy I Lecture (3-0)3
This course is the first of a three-course series which explores physical therapy management of musculoskeletal dysfunction. In this first course, general models for physical therapy intervention will be presented. The evaluation, treatment and prevention of pathological conditions affecting the musculoskeletal system of the lower extremity will be emphasized. Normal function will be included as a basis for recognizing and therapeutically resolving dysfunction of skeletal and joint structures, muscles and soft tissues. A problem-solving approach will be utilized in providing patient care.

34.609 Medical Surgical Conditions (3-0)3
This course is an introduction to the study of disease and provides an overview of common medical surgical conditions encountered by the physical therapist. Mechanisms of normal cell growth, cell response to injury and inflammation and cell death are reviewed. This is followed by an introduction to neoplastic disease and oncology. Emphasis is placed on inherited and acquired immunodeficiency disorders, infectious diseases, medical genetics, endocrine and metabolic disorders, gastrointestinal, hepatic and pancreatic disorders, nephrology and disorders of the integumentary system. Special emphasis is placed on the physical therapist's role in the clinical management of clients with selected diseases and conditions. The second half of this course focuses on diseases and conditions of the musculoskeletal system with an emphasis on the medical/surgical management of various orthopedic conditions.

34.610 Musculoskeletal Physical Therapy I Lab (0-3)1
This laboratory course encourages the development of the psychomotor skills to allow clinical application of didactice knowledge gained in Musculoskeletal Physical Therapy I Lecture.

34.611 Ethics and Professional Issues in Physical Therapy (3-0)3
This course provides physical therapy students with the conceptual, moral-reasoning and interactional abilities required to deal with ethical and professional issues in their daily practice. Readings, case studies and small group discussions allow for development and reinforcement of necessary intellectual and interactional skills. An understanding and appreciation of the profession of physical therapy including history, national organization scope of practice and Code of Ethics will be developed. Additional topics include the identification of moral aspects of health care practice, valid consent or refusal of treatment, issues of patient competency or incompetency, confidentiality, negligence and malpractice. Legal topics include consent laws, statutory and practice laws, and laws related to negligence and malpractice.

34.612 Cardiopulmonary Physical Therapy (3-0)3
Cardiopulmonary Physical Therapy provides instruction in a variety of pathological cardiopulmonary conditions encountered by physical therapists. The course emphasizes assessment and treatment procedures employed by physical therapists in dealing with these conditions. Students will be expected to integrate and synthesize information from related courses in a variety of cardiopulmonary problem solving experiences

34.613 Principles of Clinical Teaching (3-0)3
This course focuses on the principles of teaching and learning theory and the dynamics of teacher effectiveness as it applies to physical therapy and the clinical setting. Discussions will center on the identified qualities of organization, clarity, enthusiasm, stimulation, instructor knowledge, the ability to instruct in a group and the ability to supervise in a treatment setting. Emphasis is placed on creating a climate that encourages learning. A teaching experience will be planned, implemented and evaluated by each student.

34.614 Cardio-Pulmonary Physical Therapy Laboratory (0-3)1
This course is to be taken concurrently with the Cardio-Pulmonary lecture. Students will be given the opportunity to practice those procedures discussed in lecture and must demonstrate proficiency in each procedure to successfully complete the course.

34.615 Clinical Education Experience I (0-8)2
A six week full time clinical experience designed to integrate basic physical therapy evaluative and treatment procedures with an emphasis on the musculoskeletal and cardiopulmonary systems. Students are directly supervised by qualified physical therapists in general acute facilities and outpatient settings.

34.616 Research Methods (3-0)3
This course presents the role of research in the development and critical analysis of physical therapy clinical practice. Students are guided through the scientific research process and the following stages are discussed: problem and hypothesis identification, review of the literature, methods of evaluating the hypothesis, data collection, data analysis, interpretation and presentation of the results. Students will work in small groups to develop the components of a research proposal and orally present this proposal to other members of their class.

34.617 Neurological Physical Therapy I (3-0)3
This course is the first of two courses dealing with the therapeutic management of adult patients with neurological dysfunction. A variety of assessment and treatment procedures available to the physical therapist will be explored. Integration of treatment approaches will be emphasized. Theoretical models based on normal sensorimotor development, neurophysiology and motor control, and motor learning will be discussed as a base for clinical decision making. Concurrent laboratory sessions will emphasize the development of specific psychomotor skills necessary for the successful assessment and treatment of adult patients.

34.618 Management in Physical Therapy (3-0)3
This course provides an overview of the operation of physical therapy services within the structure of the United States health care system. The course will evolve from a macro approach concerning the issues and trends in the delivery of health care and their implications for the management of physical therapy services, to a micro view exploring the function and interaction of the physical therapist within the health care organization.

34.619 Neurological Physical Therapy I Lab (0-3)1
Through classroom laboratory experiences, the student will be given the opportunity to gain beginning skill in the practical application of assessment and treatment procedures for patients with neurological dysfunction.

34.620 Neurological Physical Therapy II Lecture (3-0)3
This course is the second of two courses dealing with the therapeutic management of adult patients with neurological dysfunction. A variety of assessment and treatment techniques available to the physical therapist will be explored. Integration of treatment approaches will be emphasized. Theoretical models based on normal sensorimotor development, neurophysiology and motor control, and motor learning will be used as a base for clinical decision making. Concurrent laboratory sessions will emphasize the development of specific psychomotor skills necessary for the successful assessment and treatment of adult patients.

34.621 Musculoskeletal Physical Therapy II Lecture (3-0)3
This course is the second of a three-course series which focuses on physical therapy management and summarizes medical and surgical management of musculoskeletal dysfunction. The evaluation, treatment and prevention of pathological conditions affecting the upper extremity and distal lower extremity will be emphasized. Normal function will be included as a basis for recognizing and therapeutically resolving dysfunction of skeletal and joint structures, muscular and soft tissue. A problem-solving approach will be utilized in providing patient care.

34.622 Neurological Physical Therapy II Lab (0-3)1
Through classroom laboratory experiences, the student will be given the opportunity to gain continued skill in the practical application of assessment and treatment procedures for patients with neurological dysfunction.

34.623 Musculoskeletal Physical Therapy II Lab (0-3)1
This laboratory course develops the psychomotor skills to allow clinical application of didactic knowledge gained in Musculoskeletal Physical Therapy II Lecture.

34.624 Directed Research (3-0)3
This course is the application of research design and methodology culminating in the completion of a project or thesis under the guidance and supervision of the faculty. Comprehensive case studies will also be presented and discussed.

34.625 Electrophysiological Procedures (3-0)3
This course is a study of advanced physical therapy procedures which utilize electrophysics and electrophysiology in evaluating and treating patients. The course will emphasize theories and techniques used in electrodiagnosis, electromyography, functional electrical stimulation, iontophoresis, transcutaneous electrical stimulation, biofeedback, laser and therapeutic electrical currents.

34.626 Geriatric Physical Therapy (3-0)3
The focus of this course is the changes in the cardio-pulmonary, musculoskeletal and neurological systems of the elderly that will affect physical therapy management. Emphasis is placed on special needs of the elderly with respect to exercise, psychosocial and nutritional needs and pharmacology and compliance issues.

34.627 Electrophysiology Procedures Laboratory (0-3)1
This course is a practical application of theories and principles presented in 34.625, Electrophysiology Procedures.

34.628 Musculoskeletal Physical Therapy III Lecture (3-0)3
This course is the last in a three-course series which focuses on physical therapy management and summarizes medical and surgical management of musculoskeletal dysfunction. The evaluation, treatment and prevention of pathological conditions affecting the spine, posture and gait will be emphasized. Orthotic and prosthetic use will be included. Normal function will be included as a basis for recognizing and therapeutically resolving dysfunction of skeletal and joint structures, muscular and soft tissue.

34.629 Research Seminar (2-0)2
During this course students will develop a master's project/thesis proposal with the guidance of a faculty project advisor, and instructor of the Research Seminar. This course will serve as a forum for presenting, discussing and critiqueing the students' research proposal.

34.630 Musculoskeletal Physical Therapy III Lab (0-3)1
This laboratory course develops the psychomotor skills to allow clinical application of didactic knowledge gained in Musculoskeletal Physical Therapy III Lecture.

34.631 Pediatric Physical Therapy (3-0)3
This course focuses on evaluation and treatment of pediatric problems of the CNS and neuromusculoskeletal systems. The development of a theoretical model for evaluation and treatment will be based upon principles of sensorimotor development, neurophysiology, motor control, and motor learning. The course will begin with normal sensorimotor development, evaluation and facilitation of sensorimotor development. The next section will deal with evaluation of problems in sensorimotor development, treatment techniques and strategies. The final section will emphasize problem solving and integration of previously presented material using case studies.

34.633 Pediatric Physical Therapy: Laboratory/Clinic (0-3)1
Through classroom and clinical laboratory experiences, the student will be given the opportunity to gain beginning skill in the physical therapy treatment of pediatric clients.

34.634 Clinical Education Experience II (0-8)2
An eight week full time experience which promotes the development of an autonomous professional through the synthesis and utilization of advanced academic theory in evaluation and treatment. Students are expected to use sound scientific rationale and a problem solving approach in all aspects of patient care. Students are allowed to explore areas of interest in a variety of settings.

34.635 Clinical Education Experience III (0-8)2
Final full time eight week clinical experience designed to promote socialization into the profession of physical therapy. Students are expected to function as independently as possible using the problem solving process as a basis for all clinical decision making. Communication, coordination and consultation with other members of the health care team and responsibility for total client management is emphasized.

College of Management Science

Master of Business Administration Program

Dean: Harvey Kahalas, Professor; B.S., Boston University; M.B.A., University of Michigan; Ph.D., University of Massachusetts (Amherst).
MBA Program Director: Stuart C. Freedman, Professor; B.A., City College of New York; M.S., Ph.D., Cornell University.
Faculty: Shimon Awerbuch, Assistant Professor; B.S., M.S., Ph.D., Rensselaer Polytechnic Institute; William Burke, Professor; B.A. University of Massachusetts (Amherst); M.Ed., Boston State College; J.D., Suffolk University Law School; Harrison Campbell, Associate Professor; S.B. Massachusetts Institute of Technology; A.M., Ph.D., Columbia University; Severin C. Carlson, Associate Professor; B.S., Northeastern University; M.B.A., D.B.A., Indiana University; Clairmont P. Carter, Professor; B.S., Pennsylvania State University; M.B.A., University of Akron; D.B.A., Kent State University; Michael Carter, Assistant Professor; B.A., Yale University; M.A., Ph.D., Stanford University; Albert M. Cederlund, Professor; A.B., Clark University; M.S., Columbia University; Ph.D., Clark University; Samuel Chesler, Associate Professor; B.S., Boston University; M.B.A., Suffolk University; H. Michael Coiner, Assistant Professor; B.A., Princeton University; M.A., Ph.D., Yale University; J. Stephen Collins, Associate Professor; B.A., Boston College; M.S., Northeastern University; Ph.D., Boston College; C.P.A. (Massachusetts); Clare L. Comm, Associate Professor; B.S., Miami University (Ohio); M.B.A., University of Ohio (Dayton); Ph.D., University of Cincinnati; Ellen Foster Curtis, Associate Professor; A.B., M.B.A., D.B.A., Indiana University; Leslie M. Dawson, Professor; B.B.A., Iona College; M.A., University of Toledo; Ph.D., Michigan State University; George C. Dery, Associate Professor; A.B., Merrimack College; M.A., Boston College; Gerald F. Downey, Professor; B.S., M.B.A., Northeastern University; M.S., Ph.D., Boston College; Richard E. Ducharme, Professor; B.S., Syracuse University; M.S., Air Force Institute of Technology (Ohio); Ph.D., Syracuse University; David P. Echevarria, Assistant Professor; B.A., Chapman College; M.B.A., University of West Florida; Ph.D., University of Massachusetts (Amherst); Charles T. Feeney, Professor; B.S., Boston College; M.B.A., Northeastern University; C.P.A. (Massachusetts); John G. Hamer, Associate Professor; B.S., University of Lowell; M.B.A., Ph.D., Texas A & M University; Brooke Hargreaves-Heald, Assistant Professor; B.A., Brandeis University; J.D., Northeastern University; Braxton Hinchey, Professor; A.B., M.A., Ph.D., University of Missouri; Thomas J. Hogan, Assistant Professor, B.S., University of Massachusetts (Amherst); M.B.A., University of Washington; Ph.D., University of Massachusetts (Amherst); C.P.A. (Massachusetts); Michael E. Jones, Associate Professor; B.A., Denison University; M.B.A., University of Pennsylvania; J.D., University of Miami; Timm L. Kainen, Professor; B.A., Connecticut State University, M.A., University of Hartford; Ph.D., University of Massachusetts (Amherst); Russell R. Karl, Associate Professor; B.S.B.A., Bryant College; M.S., Suffolk University; J.D., Suffolk University Law School; M. Riaz Khan, Professor; B.S., M.S., University of Karachi (Pakistan); M.A., M.B.A., Ph.D., State University of New York (Buffalo); Valerie Kijewski, Assistant Professor; B.A., Boston College; M.A., Ph.D., Indiana University; Linda H. Kistler, Professor; B.S., M.S., Colorado State University; C.P.A. (Massachusetts); Anne M. Koen, Assistant Professor; B.S.B.A., University of Lowell; J.D., Suffolk University Law School; L.L.M., Boston University; C.P.A. (Massachusetts); Ramakrishnan S. Koundinya, Associate Professor; B.S., M.A., M.S., University of Madras (India); M.S., Carnegie Mellon University; Ph.D., New York University; Sarah Kuhn, Assistant Professor; B.A., Harvard University; Ph.D., Massachusetts Institute of Technology; Duncan G. LaBay, Assistant Professor; B.A., University of Southern Maine; B.S., M.A., Tufts University; Ph.D., University of Michigan; Supriya Lahiri, Assistant Professor; B.A., University of Calcutta; M.A., University of Delhi; Ph.D., Delhi School of Economics; Joshua B. Levy, Assistant Professor; B.A., State University of New York at Binghamton; M.A., University of Wisconsin; M.S., Cornell University; Ph.D., University of Wisconsin; David A. Lewis, Associate Professor; B.S.I.E., Northwestern University; M.S.I.E., University of Texas (Arlington); Ph.D., University of Massachusetts (Amherst); George T. Liaw, Associate Professor; B.A., National Taiwan University; M.A., University of Minnesota; Ph.D., University of Illinois (Urbana); Thomas C. Macbeth, Professor; A.B., Cornell University; M.A., Ph.D., University of Southern California; Efrem G. Mallach, Associate Professor; B.S.E., Princeton University; M.B.A., Boston University; Ph.D., Massachusetts Institute of Technology; Stuart L. Mandell, Professor Emeritus; B.A., Brooklyn College; M.B.A., Syracuse University; William Mass, Associate Professor; B.G.S., University of Michigan; M.P.H., Harvard University; Ph.D., Boston College; Carol C. McDonough, Professor; B.A., Marymount Manhattan College; M.A., Ph.D., Boston College; Joyce S. Mehring, Associate Professor; B.A., Bucknell University; M.S., University of Michigan; Ph.D., Massachusetts Institute of Technology; James P. Monahan, Professor; B.S., M.B.A., Boston College; Ph.D., Columbia University; Martin R. Moser, Associate Professor; B.A., The City College of New York; M.A., Antioch Graduate School of New England; Ph.D., University of Massachusetts (Amherst); Phillip I. Moss, Associate Professor; B.A., Johns Hopkins University; Ph.D., Massachusetts Institute of Technology; Daniel Pearl, Associate Professor; B.A., M.S., Ph.D., University of Minnesota; Leo Pipino, Associate Professor; B.S.E.E., Manhattan College; M.S.E.E., Northeastern University; Ph.D., University of Massachusetts (Amherst); Richard E. Plank, Assistant Professor; B.S., St. Peters College; M.B.A., Seton Hall University; Ph.D., City University of New York; Santo J. Pullara, Professor; B.S., M.B.A., J.D., Ph.D., Syracuse University; Yash R. Puri, Professor; B.Sc., M.Sc., Delhi University, M.B.A., D.B.A., Indiana University; Jean L. Pyle, Assistant Professor; B.A., Bucknell University; M.A., University of Michigan; Ph.D., University of Massachusetts (Amherst); James E. Samels, Assistant Professor; B.A., University of Massachusetts (Amherst); M.P.A., University of Rhode Island; J.D., Suffolk University Law School; Ed..D., University of Massachusetts (Amherst); Ernesto F. Sanz, Associate Professor; B.A., Loyola University (Spain); M.A., Kamakura Language College (Japan); M.A., Sophia University (Japan); Ph.D., Boston College; Irwin A. Shapiro, Professor; B.S., Syracuse University; M.B.A., Indiana University; M.A., Ph.D., Clark University; Timothy P. Shea, Instructor; B.S., Boston College; M.B.A., Indiana University; Pamela D. Sherer, Assistant Professor; B.A., Carthage College; M.S., Southern Illinois University; M.B.A., Clark University; Ph.D., University of Massachusetts (Amherst); Mayda Shorney, Assistant Professor; B.A., Oklahoma Baptist University; Ph.D., Texas A & M University; C.P.A. (Oklahoma); Balbir S. Sihag, Professor; B.A., Dayanand College (India); M.A., Punjab University (India); Ph.D., Massachusetts Institute of Technology; Paul E. Snoonian, Associate Professor; B.S., M.B.A., Northeastern University; M.A., Ph.D., Michigan State University; Kathleen Suchon, Assistant Professor; B.A., University of California (Berkeley); M.B.A., Ph.D., State University of New York (Albany); Charles F. Thompson, Associate Professor; B.S.A., Bentley College; M.B.A., Northeastern University; C.P.A. (Massachusetts); Chris Tilly, Assistant Professor; B.A., Harvard College; Ph.D., Massachusetts Institute of Technology; Kathryn M. Verreault, Associate Professor; B.S., University of Lowell; M.B.A., Ph.D., Texas A & M University; Rudolph Winston, Jr., Associate Professor; A.B., Haverford College; M.B.A., Columbia University; D.B.A., Harvard University; Louis E. Yelle, Professor; B.S., Lowell Technological Institute; M.S., M.B.A, Northeastern University; Eunsang Yoon, Assistant Professor; B.A., Seoul National University; M.B.A., University of Georgia; Ph.D., Pennsylvania State University.

The Master of Business Administration (M.B.A.) Degree Program

American business in the 1990's will be facing very different internal and external environments than existed in prevous decades. Increasing internationalization, along with rapid changes in manufacturing, markets, financing, information technology and labor force demographics are already influencing business in significant ways. These changes directly affect the health and vitality of our region's and nation's economy.

The goal of the M.B.A. program, which is fully accredited by the American Assembly of Collegiate Schools of Business, is to address these issues by offering a high quality course of study that prepare graduates to function effectively under swiftly evolving regional, national and global conditions. To achieve this goal, the program emphasizes adaptability and creativity on the part of both managers and organizations. Students learn the core technical and conceptual skills necessary to ob jectively evaluate business conditions both inside and outside the firm. The intent is to produce graduates who will be able to apply new approaches to design and implement flexible work systems that allow an organization to act before conditions force it to react.

With this philosophical framework as its driving force, graduates of the M.B.A. program at Lowell are prepared to become leaders in a wide variety of commercial, industrial and governmental settings. Advanced courses are available in the fields of finance, human resources, management, marketing, and operations management. Students will also have the opportunity to create individualized programs that focus on issues of current concern in business that cross disciplinary boundaries.

The awarding of the M.B.A. degree signifies that the student has developed integrative skills in problem solving and decision making, and can relate these skills to all functional areas of business. The development of this expertise entails a thorough examination of advanced analytical tools, both theoretical and practical and intensive training in their application through exposure to a wide range of topical cases.

Graduate Assistantships

Teaching and research assistantships are available to many qualified full-time M.B.A. students in the College of Management Science (C.M.S.). These awards provide students with a stipend for the academic year, along with a waiver of tuition. The primary purpose of these awards is to provide promising graduate students with financial assistance to offset the costs of full time graduate study. They also benefit students by providing an opportunity to build knowledge and skill in various aspects of business administration by working closely with members of the C.M.S. faculty in the conduct of their teaching and research.

Computer Facilities

Full-time and part-time M.B.A. students have access to extensive computer facilities both inside and outside of the College. Within the College, students may utilize a Digital VAX 8350, and numerous IBM-compatible microcomputers located in the C.M.S. microcomputer laboratory. Also available is the University's Digital VAX 8650. Use of this equipment, as part of course work or in conducting research, familiarizes students with computer technology in general, and provides them with specific micro and mainframe computer skills that are vital for success in today's business world.

Entrance Requirements

Admission to the M.B.A. program is open to students who have earned the baccalaureate degree. An aptitude for management decision-making and demonstrated academic ability are the most important qualifications for admissions. It is also recommended that applicants have an adequate mathematics background, including exposure to calculus. Applicants should submit, along with their Graduate School application, an official transcript of grades from their undergraduate institution(s), an official Graduate Management Admission Test (G.M.A.T.) score (the Graduate Record Examination is not an acceptable alternative), three letters of recommendation, and a one-page typewritten statement of academic and career goals.

Part-time and Full-time Study

M.B.A. students may attend either full-time or part-time. Most courses, at present, meet during the evening hours beginning at 5:00 p.m. or 6:00 p.m. Some courses meet during the day beginning at 3:00 p.m. Courses are offered in the fall and spring semesters and in two intensive summer sessions. A normal full-time course load is considered to be 9 credits. Full-time students usually complete their degree requirements within two and a half years. Students must complete their degree requirements within five years.

Admission to M.B.A. Courses

M.B.A. courses are open only to College of Management Science graduate students who are fully-matriculated degree candidates. Applicants to the M.B.A. program may not take courses while their application is being completed or under review.

Application deadlines are:

For Fall Admission

International applicants:	April 1
U.S. residents:	June 1

For Spring Admission

International applicants:	November 1
U.S. residents:	December 1

Residency Requirement

To be recommended for the M.B.A. degree, students are required to complete a minimum of ten courses (30 credits) in the M.B.A. program at the University of Lowell. After admission to the program, students are expected to complete all course work at the University. Only under special circumstances, and with prior approval, are students permitted to complete courses at other institutions.

Waiver of Courses

In some cases it may be possible for students to waive various required core courses in recognition of previous undergraduate or graduate business courses completed at other schools with a minimum grade of "B". The M.B.A. program office has specific guidelines regarding waivers which may be reviewed by interested students. In all cases, core course waivers must be approved by the M.B.A. Program Director. Advanced courses (up to 6 credits) may be waived for graduate courses previously completed with a minimum grade of "B" at other A.A.C.S.B. accredited schools.

Curriculum Requirements

The M.B.A. program consists of sixty credit hours (20 3-credit courses). The distribution of credits is: twenty-seven hours of core courses, six hours of advanced core courses, twelve hours of concentration courses, and fifteen hours of electives. All required core courses must be completed before any advanced, concentration or elective courses may be taken.

Required Core Courses

(9 courses-27 credits):

60.632	Financial Accounting
61.601	Business Financial Analysis
62.601	Marketing Fundamentals
63.672	Operations Management
63.602	Management Information Systems
64.611	Quantitative Analysis
64.603	Managerial Economics
66.601	Organizational Behavior
66.602	Law and Society

Required Advanced Core Courses

(2 courses-6 credits):

66.781	Corporate Strategy (must be taken in the last semester)
66.783	International Business

Area of Concentration Courses
(4 courses-12 credits)

Courses must be taken in the prescribed sequence shown for each concentration.

Finance
61.731 Financial Management
61.736 Portfolio and Security Analysis
61.738 International Finance
61.xxx Finance Elective

General Management
60.612 Managerial Accounting
61.731 Financial Management
62.680 Marketing Analysis and Planning

Select one from the following:
63.772 Operations Planning and Control
63.673 Operations Research

Marketing
62.610 Marketing Research
62.xxx Marketing Elective
62.xxx Marketing Elective
62.680 Marketing Analysis and Planning

Operations Management
63.772 Operations Planning and Control
63.673 Operations Research
63.773 Advanced Operations Research
63.xxx Operations Management Elective

Human Resources Management
66.652 Human Resources Management
66.774 Industrial Relations
66.xxx Human Resource Elective
66.xxx Human Resource Elective

Elective Courses (5 courses-15 credits):
This is the "breadth" part of the program and therefore may not include any courses from the student's area of concentration with the exception of General Management. Also, not more than two (2) courses may be included from any other area of concentration.

Course Descriptions

60.601 Financial Accounting (3-0)3
An examination of financial statements which are provided to users external to the economic enterprise. Accounting procedures, financial accounting concepts, and the fundamentals of financial statement analysis and interpretation.

60.612 Managerial Accounting (3-0)3
Prerequisite: 60.601
The uses of accounting information by internal management. Product costing systems, cost allocation methods, budgeting and forecasting techniques, and altemative decision tools and methods.

60.631 Federal Income Taxes (3-0)3
Prerequisite: 60.601
The basic rules and regulations of the Internal Revenue Code as it affects individuals and business firms. The role of taxation in the business decision making process. The tax effects of alternative types of organization, depreciation and inventory methods, mergers and acquisitions, and other important topics.

60.752 Accounting Information Systems (3-0)3
Prerequisite: 60.612
The design and development of computer-based accounting information systems (AIS). The role of AIS as part of the organization's information and control system.

60.690 Current Topics in Accounting (3-0)3
Prerequisite: 60.601
Selected topics having current and future impact in the field of accounting.

60.700 Independent Study in Accounting (3-0)3
Prerequisite: 60.601 and permission of the instructor.

61.601 Business Financial Analysis [61.632] (3-0)3
Prerequisite: 60.632
A study of financial principles and organization of the business enterprise with emphasis on financial analysis, management of working capital, sources and cost of capital, and capital budgeting. Business cases, problems, readings and reports.

61.731 Financial Management (3-0)3
Prerequisite: 61.632
The optimum management of funds in a business organization and the techniques of financial analysis. Topics include valuation of the firm, capital budgeting, cost of capital, decisions under uncertainty, management of working capital, and other related topics.

61.732 Financial Markets and Institutions (3-0)3
Prerequisite: 61.632
Analysis of the theory and practice of financial intermediation by institutions in the financial markets.

61.736 Portfolio Investment and Security Analysis (3-0)3
Prerequisite: 61.601
Development of investment theory as applicable to portfolio management and securities selection.

61.738 International Financial Management (3-0)3
Prerequisite: 61.632
The international dimension of the finance function of the firm. Financial constraints of the international environment and their effect on the standard concepts of financial management. The techniques of adapting risk analysis to the international situation. Study of international currency flows, monetary systems, forward cover and international banking policies.

61.737 Current Topics in Finance (3-0)3
Prerequisite: 61.632
Selected topics having current and future impact in the field of finance.

61.739 Independent Study in Finance (3-0)3
Prerequisite: 61.632 and permission of instructor

62.601 Marketing (3-0)3
How marketing strategies and plans of a competitive enterprise are formulated, implemented, and adjusted over time. Behavioral and quantitative aspects are covered, as well as analysis of the environmental forces affecting marketing decisions.

62.610 Marketing Research (3-0)3
Prerequisite: 62.601
The formulation, execution, and interpretation of marketing research projects, within the broader context of a marketing intelligence system. Research design, data collection methods, and sampling theory.

62.640 Consumer Behavior (3-0)3
Prerequisite: 62.610
Application of theories and techniques from the behavioral sciences to the understanding of consumer problem identification and purchasing processes. Cases in the formulation of marketing strategies based upon appropriate behavioral models.

62.650 Industrial Marketing (3-0)3
Prerequisite: 62.610
Product development, distribution, pricing and promotional policies for companies marketing to industrial firms, resellers and governmental agencies.

62.660 Marketing Communications (3-0)3
Prerequisite: 62.610
The social and economic role of promotion, and the historical development of mass media and advertising. Advertising research, creation and production as a tool of marketing management.

62.670 International Marketing (3-0)3
Prerequisite: 62.610
Cases in cultural dynamics, economics, political and legal constraints as they affect strategic market planning for international business.

62.680 Marketing Analysis and Planning (3-0)3
Prerequisites: 62.610 plus two marketing electives
Managerial decision-making aspects of marketing including design and use of models, marketing's organizational relationships, utilization of market research data, and performance evaluation and control through marketing audits.

62.690 Current Topics in Marketing (3-0)3
Prerequisite: 62.601
Selected topics having current and future impact in the field of marketing.

62.700 Independent Study in Marketing (3-0)3
Prerequisites: 62.680 and permission of instructor.

63.672 Operations Management (3-0)3
Prerequisite: 64.601
The techniques and models used in operations management. Topics include production design and process planning, layout of physical facilities, production standards and work methods, job evaluation, forecasting and scheduling, inventory systems, quality control, and the use of simulation in manufacturing operations.

63.673 Operations Research (3-0)3
Prerequisite: 63.672
Operations research techniques useful in business and management decision-making. Topics include classical optimization, linear programming, dynamic programming, queuing theory, Markov chains and simulation methods.

63.772 Operations Planning and Control (3-0)3
Prerequisite: 63.672
An examination of the complex decisions faced by the operations manager. Topics include the design of forecasting, production planning, inventory control, and quality control systems, and how each of these systems is integrated into the firm as a whole. Cases and readings used extensively.

63.773 Advanced Operations Research (3-0)3
Prerequisite: 63.673
A study of dynamic programming, integer programming and combinatorial models, stochastic programming models, probabilistic inventory models and waiting line models. The significance of the models, their potential problem solving capabilities and limitations, including computational experience and applications.

63.775 The Practice of Operations Management (3-0)3
Prerequisite: 66.672, and 66.673 or permission of instructor
An application of the student's quantitative skills to identify, model and solve actual operational problems in local business firms. Problem areas addressed include product mix decisions, facility layout and location, transportation and distribution, carrier selection, and inventory stocking policies. Modeling techniques used include linear programming, decision theory and simulation.

63.690 Current Topics in Operations Management (3-0)3
Prerequisite: 63.672
Selected topics having current and future impact on the field of operations management.

63.700 Independent Study in Operations Management (3-0)3
Prerequisite: 63.672 and permission of instructor.

63.602 Management Information Systems (3-0)3
Prerequisite: 60.601
An examination of how computers can be used in business for processing business data and for providing information for decision making. The current capabilities of computer hardware and software; business application throughout the organization, from transaction systems to decision support systems (DSS) to executive information systems (EIS), as well as office and factory automation.

63.603 Advanced Management Information Systems (3-0)3
Prerequisite: 63.602 or permission of instructor.
The study of two key computer technologies: data base management and data communications. These are applied to various business computer systems such as distributed processing systems, on-line real-time systems, office automation, factory automation, and decision support systems. Other topics include control and auditing, documentation standards, as well as legal and social aspects of data processing.

63.691 Current Topics in Management Information Systems (3-0)3
Prerequisite: 63.602
Selected topics having current and future impact on the field of Management Information Systems.

63.701 Independent Study in Management Information Systems (3-0)3
Prerequisite: 63.602 and permission of the instructor.

64.601 Quantitative Analysis [64.611] (3-0)3
Introductory statistics and its role in business. Topics covered include variables and their distribution, sampling theory, hypothesis testing, simple and multiple regression, correlation, and decision theory.

64.602 Managerial Economics (3-0)3
Prerequisite: 64.601
An examination of consumer demand theory, production and cost theory and pricing policy under alternative market structures. Statistical estimation of demand, production and cost functions.

64.620 Macroeconomic Analysis and Policy (3-0)3
Prerequisite: 64.602
Alternative frameworks for explaining the behavior of national aggregates such as gross national product, levels of employment and unemployment, price levels, and levels of income. The role of fiscal and monetary policies in influencing the values of these national indicators; an appraisal of the causes and consequences of federal budget deficits and foreign trade deficits.

64.700 Independent Study in Economics (3-0)3
Prerequisite: 64.602 and permission of instructor.

66.601 Organizational Behavior (3-0)3
The relationship between the individual and the organization in terms of organization design and change, leadership, motivation, communications, group dynamics, conflict resolution, decision-making, interpersonal relations, and career development.

66.602 Law and Society (3-0)3
An introduction to the study of law and the legal environment in which business functions. This course covers the elements of macro-law (governmental agencies and law) as well as micro-law (private historical law). Topics include product liability, employment law, business ethics, contract law, security regulation, business organization, and the uniform commercial code section that has been internationalized.

66.610 The Regulatory Environment (3-0)3
Prerequisite: 66.602
Introduces the business student to the public law regulations and case law decisions affecting the business corporation.

66.620 Property Law (3-0)3
Prerequisite: 66.602
The general principles of the law of property, and legal requirements for acquiring and transforming different property interests. Leases, bailments, cooperatives, real estate agents, condominium law, land use regulation, trusts, and wills are emphasized.

66.630 Managing Engineers, Scientists and the R&D Function (3-0)3
Prerequisite: 66.601
An overview of the characteristics unique to managing an R&D unit, and how the R&D unit relates to the ongoing functioning of the entire organization. The course provides experiences in applying behavioral, economic and managerial techniques to the design and management of research, development and engineering personnel.

66.652 Human Resources Management (3-0)3
Prerequisite: 66.601
Recruitment, selection, training, human resource planning, compensation management, equal employment opportunity, performance evaluation, management development, discipline, and employee health and safety. The role of the human resource executive in corporate management and strategic planning.

66.670 International Law (3-0)3
Prerequisite: 66.602
The rules, principles, customs and laws that are in force between nations and which govern international commerce and trade. Specific subjects include issues of jurisdiction and responsibility, territoriality and nationality, legal aspects of trade restrictions, licensing agreements, import/export requirements, and the extraterritorial application of U.S. law.

66.690 Current Topics in Management (3-0)3
Prerequisite: 66.601
Selected topics having current and future impact in the field of management.

66.691 Current Topics in Business Law [61.690] (3-0)3
Prerequisite: 66.602
Selected topics having current and future impact on the field of business law.

66.701 Starting New Ventures (3-0)3
Prerequisite: 66.601
The role of the entrepreneur in today's business world, and the traits commonly associated with successful entrepreneurship. The processes of new venture selection and start-up are examined via the use of appropriate cases.

66.704 Consulting Strategies and Practices (3-0)3
Prerequisite: Permission of the instructor.
An integration of management theory and practice via an intensive examination of the management consulting literature coupled with actual consulting experience with local business firms under the supervision of a faculty member.

66.752 Organization Design and Change (3-0)3
Prerequisite: 66.601
How general managers can create, rearrange and improve organization structures and sub-units. Identifies design and change methods for more efficiently controlling and directing behavior toward the achievement of corporate goals and strategies. This course integrates Organizational Behavior and Business Policy.

66.753 Compensation Management (3-0)3
Prerequisite: 66.601
Theories and practices in compensation management. Topics include pay equity, job analysis, job evaluation, legal issues, salary surveys, pay structure design, individual pay decisions, incentive plans, economic constraints and the role of unions.

66.754 Planning Management Careers (3-0)3
Prerequisite: 66.601
Two approaches to planning careers in management are examined; first, the assessment of personal growth and development through individual career stages and life cycles; and second, the analysis of managerial skill and task requirements created by different organizations at various stages of their own design and change.

66.755 Human Resource Planning (3-0)3
Prerequisite: 66.601
The design and implementation of human resource planning (HRP) systems in organizations. The use of HRP techniques in support of changing business objectives and strategies, labor market characteristics, economic conditions, and legal and regulatory constraints. Extensive use of cases and exercises as a foundation for classroom instruction.

66.774 Industrial Relations (3-0)3
Prerequisite: 66.601
A study of public policy toward labor-management relationships. Regulation by the National Labor Relations Board, collective bargaining, arbitration, civil rights, and the application of anti-trust law to unions.

66.781 Corporate Strategy (3-0)3
Prerequisite: Last course in M.B.A. Program. This integrative course is taken in the last semester of the program. The emphasis is on strategic long-range planning and decision making from the perspective of the firm's chief executive officer. Extensive case analyses illustrate the inter-relationships among the various functional areas of business.

66.783 International Business (3-0)3
Prerequisites: 61.601, 62.601, 63.672, 66.601
An examination of private versus government interests in international business, as well as the functional areas of international business operations with emphasis on marketing and finance.

66.789 Independent Study in Management (3-0)3
Prerequisites: 66.601

66.790 Independent Study in Business Law (3-0)3

Business Management Curriculum for the Doctor of Engineering (Eng. D.) Program

Management Program Coordinator: Valerie Kijewski, Assistant Professor, B.A., Boston College; M.A., Ph.D., Indiana University.

The philosophy and goals of the management component of the Doctor of Engineering program are as follows:

The aim is to develop a person who can effectively extend the limits of technology both as a member of a professional work team and as a member of a global society. Today's professionals will find that, over their work lives, they will hold several different types of positions in fields using their professional education – in the business world, in academia, or in other endeavors. Regardless of the environment, a core of "management" skills will be required for success. The professional must be able to understand the external and internal work environment, understand the criteria that form the basis for decisions, and understand and evaluate the implications of those decisions.

To achieve these goals, the College of Management Science has established the following objectives for the management curriculum of the Doctor of Engineering program:

1. *Overview of Management and Organizations*
   - Proficient with management concepts and functions
   - Skills to function effectively in complex organizations
   - Ability to understand and initiate change in both organizations and infrastructures
   - Prepared to champion, as either entrepreneur or entrapreneur, new ideas or products
2. *Appreciation of the Environment of Business*
   - Understanding of the business and technological implications of the global concept
   - Understanding of the social/legal/ethical interactions of business and technology in the institutional and social environment
3. *Development of Evaluation/Planning Implementation Skills*
   - Understanding technological innovation/diffusion processes and implications for resource allocation and action programs
   - Capability to measure profit potential implications of new technology and products
   - Ability to evaluate strategic business implications of technological decisions
   - Capability to evaluate the profit and market implications of alternative policy and strategy options

In summary, the candidate should have the capabilities to understand and make key business decisions, develop, implement, and alter strategic initiatives, and effectively serve as a leader in an organizational setting.

The management curriculum for the Doctor of Engineering program is a free-standing, self-contained package of courses. These courses do not assume a previous knowledge of business or management subjects by the engineer. All of the courses must be completed in the prescribed order over four consecutive semesters beginning in any fall semester. Once the student begins, he or she must complete the entire sequence of courses with his or her class. This allows for curriculum integration by faculty and the formation of work/study groups by students. The courses are only open to Engineering doctoral students.

The following courses were offered in the 1989-1990 academic year. This list is subject to change.

66.801 Organizational Behavior for the Engineering Manager (2-0)2
An in-depth application-oriented understanding of how organizations are structured, the behavior and interactions of people in them, and the techniques by which both people and organizations are effectively managed. Issues addressed include career planning, motivation and control, perception, communication, conflict management, leadership, organizational change and decision-making.

60.801 Accounting for the Engineering Manager (2-0)2
Introduction to the uses of accounting measurement. Topics include the accounting model, alternative accounting procedures, sources of financial information and financial statements. Managerial accounting topics include cost behavior, product costing, standard costing systems and budgeting. These and other issues are discussed in the context of the engineering and production functions. The student performs computer laboratory work using a general ledger package and electronic spreadsheet.

64.801 Business Economics for the Engineering Manager (2-0)2
How economic environments influence the business decision making process. An analysis of basic economic concepts such as supply and demand, price, competition, and markets. Also addressed are gross national product, money and inflation, budget and trade deficits, and the role of government fiscal, monetary, anti-trust and regulatory policies.

61.801 Finance for the Engineering Manager (2-0)2
An introduction to the basic concepts of managerial finance and their use in decision making. Also, the nature and role of financial markets. Specific topics include the management and financing of working capital, valuation, dividend policy, mergers and capital structure.

63.801 Manufacturing Management for the Engineering Manager (2-0)2
A detailed examination of the role of operations manager in a manufacturing setting. The focus is on materials and inventory management, materials requirements planning, determination of master system capacity, demand forecasting, and student simulated hands-on experience.

62.801 Marketing for the Engineering Manager (2-0)2
An introduction to the nature of the American marketing system and the processes of marketing management. Emphasis is on the role of market-oriented strategic planning. Specific topics include the consumer and industrial buyer, the product portfolio, distribution strategy, price as a marketing tool, and the development of a marketing plan.

66.801 Business Law for the Engineering Manager (2-0)2
An examination of the legal environment of business. Emphasized are the skills needed to identify legal problems and the objectives that are more readily attainable through legal means. Issues addressed include contracts, the binder, rights of third parties, agency, employment law, the law of sales and the uniform commercial code.

66.880 Business Policy for the Engineering Manager (2-0)2
This integrative course focuses on the general management function and on the skills necessary for choosing and implementing strategies that achieve organizational goals. Emphasis is on environmental analysis, identification of objectives, strategic forecasting and choice, evaluation and control, and global strategic management.

Comprehensive Examination Non-Credit
This examination is taken at the end of the spring semester after the courses have been completed. The examination covers material from all courses but is integrative rather than specific to any subject in the curriculum.

College of Music

Dean: Gerald J. Lloyd, Professor; B.M., M.M., College-Conservatory of Music, University of Cincinnati; Ph.D., Eastman School of Music, University of Rochester.
Assistant Dean: Harold A. Popp, Professor; B.M.E., Ottawa University; M.F.A., Ph.D., University of Iowa.

Objectives of Graduate Programs in Music

The graduate programs in the College of Music are committed to the continued acquisition of musical knowledge and professional competence and the development of research skills. The specific objectives of the various degree programs are listed under the individual program descriptions.

General Requirements for Admission

Applicants for admission to the Master of Music degree program must possess a bachelor's degree or its equivalent with a major in music. Those holding degrees in other disciplines will be expected to take prerequisite undergraduate courses for no graduate credit to bring their skills to a level commensurate with that attained by an undergraduate music major. Some prerequisites may be waived, at the discretion of the College, through distinguished results on placement examinations and performance auditions.

All applicants are expected to present an undergraduate record of sufficient quality to assure a reasonable expectation of successful graduate achievement. Candidates for admission must submit the required Graduate School application forms and official transcripts of previous post-secondary education.

The College of Music requires the Graduate Record Examination Aptitude Tests for admission to the programs in musicology and theory/composition. The Miller Analogies test is used for the program in music education. Each department requires additional materials or examinations which must be completed or filed by the applicant. Please review the materials below for information on individual programs.

Placement Examinations and Advising

Upon arrival, all entering graduate students are required to take placement examinations in Music Theory and Music History. The academic calendar of the College of Music should be consulted for specific test dates.

Successful candidates for admission will be assigned a faculty advisor and notified of registration dates and other pertinent information.

General Program Requirements

All Master of Music programs require a minimum of 33 credits (including 74-596, Introduction to Graduate Study in Music); a minimum of two semesters of applied music in the principal performance instrument or voice, and a minimum of two semesters of satisfactory ensemble participation. Each program requires either a thesis or recital project. Specific thesis/recital project requirements are listed under program descriptions.

Comprehensive Examinations

All degree candidates must pass a written comprehensive examination in both music theory and music history, demonstrating their understanding of basic theoretical and historical concepts. These examinations are administered twice yearly during the first week of each semester by the Academic Studies Department.

Academic Studies Department

Antone Holevas, Associate Professor and Chairperson, Music Theory and Composition; B.M., Butler University; M.M., Boston University.
Faculty: Dean Bouzianis, Associate Professor, Theory and Composition; B.M., A.M., Boston University; M.M., National Conservatory of Greece; D.M.A., Boston University; Jacqueline Charette, Associate Professor, Music Theory; B.M., Rivier College; M.M., Ed. D., Boston University; Alma O. Espinosa, Professor, Music History & Literature; B.M., Eastman School of Music; M.M., Pius XII Institute; A.M., Ph.D., New York University; Gerald J. Lloyd, Professor, Theory, Composition, History & Literature; B.M., M.M., College-Conservatory of Music, University of Cincinnati; Ph.D., Eastman School of Music, University of Rochester; Christopher McGahan, Assistant Professor, Music History and Literature; B.A., University of Massachusetts, Amherst; M.M., University of Wisconsin, Madison; D.M.A., University of Illinois, Urbana; John Ogasapian, Professor, Music History and Literature; B.M., M.A., Ph D., Boston University; Anne Trenkamp, Professor, Music Theory; M.M., University of Michigan; B.A., Ph.D., Case-Western Reserve University.

Master of Music in Musicology

Objectives of the Program

The program in musicology combines the rigor expected of graduate study in the discipline and the skills in bibliography which would also be preparatory for those persons considering doctoral work in musicology.

Admission Requirements

In addition to the general admission requirements for all applicants to the Master of Music programs, applicants to the musicology program must also submit:

- scores from the Graduate Record Examination Aptitude Test,
- a sample of expository writing demonstrating research technique (e.g., a copy of an undergraduate thesis or term paper) and,
- at least three letters of recommendation from a senior professor at the previous institution who is in a position to assess the quality of the scholarship.

Language Requirement

Musicology candidates must demonstrate knowledge of German sufficient to read scholarly literature of their field in that language with adequate comprehension. *Language requirements must be satisfied prior to taking comprehensive examinations.*

Program Requirements

74-596	Introduction to Graduate Study in Music	3
	Elective in Music Theory	3
	Applied Music	2,2
	Ensemble	1,1
	Electives in Music (500 level and above)	18
74-796	Thesis	3

Master of Music in Theory/ Composition

Objectives of Program

The degree program of Master of Music in Theory/Composition is intended to provide each candidate with the opportunity to refine the techniques of composition, to pursue advanced studies in music theory, to begin to develop approaches to research, and to become more intimately acquainted with music in a historical and stylistic context.

Admission Requirements

In addition to the admission requirements for all applicants to the Master of Music programs, applicants to the theory/composition program must submit the following.

1. Scores from the Graduate Record Examination Aptitude Test
2. A portfolio of compositions containing a work for full orchestra, a work for chamber ensemble, and a work in an optional idiom. Compositions submitted must demonstrate at least one movement in sonata form and a theme with at least five variations.
3. Representative research papers should be submitted by those who plan to concentrate in music theory.

4. Three letters of recommendation, at least one of which should be from a professor in the candidate's previous institution who is in a position to assess the quality of previous work and potential for future development.

Program Requirements

74-596	Introduction to Graduate Study in Music	3
	Minimum of One Course in Music History	3
	Applied Music	2,2
	Ensemble	1,1
	Electives in Music (500 level and above)	18
71-795	Thesis*	3

* Candidates may present either a thesis or a composition, as determined in consultation with advisor and appropriate departmental faculty.

Music Education Department

Ruth C. Ashley, Associate Professor and Chairperson; B.S.Ed., University of Lowell; M. Ed., Fitchburg State College
Faculty: Donald Bravo, Professor, Music Education; B.M., New England Conservatory; M.M., Boston Conservatory. Deborah Mitchell, Assistant Professor, Music Education; B.M.E., M.M.E., Hartt School of Music, University of Hartford; D.M.A., University of Southern California.

Master of Music in Education

Due to changes in state certification requirements in the Commonwealth of Massachusetts, the graduate program in music education will undergo modification during the 1990-91 academic year. *Persons interested in completing the Master of Music in Education degree program should contact the chair of the Music Education Department to receive information and guidance reflective of program modifications.*

Objectives

The Master of Music Education degree program is designed to facilitate students' growth and development as leaders in the profession of music education; as creative problem solvers, i.e., innovative thinkers; as individuals who love music and the arts and utilize their knowledge of and enthusiasm for music to inspire students; and as contributors, through research, to the profession.

Admission Requirements

In addition to the admission requirements for all applicants to the Master of Music programs, applicants to the music education program must submit: official score for the Miller Analogies Test, verification of teaching certificate or proof of teaching experience, at least three letters of recommendation from persons qualified to evaluate both musical and professional capabilities.

All applicants must also present an essay of no more than ten typewritten pages addressing the following points:

a. the applicant's purpose in pursuing graduate study in music education;
b. the applicant's philosophy of education in general and music education in particular;
c. an assessment of music education in the applicant's community;
d. the applicant's recommendations for improvement at all three levels: elementary, middle school and high school;
e. specific steps the applicant would take, or has already taken to implement the recommended improvements;
f. a description of the applicant's concept of an "ideal" program of graduate study in music education, which would enable the applicant to grow musically and academically, and which would contribute significantly to the applicant's effectiveness as a music educator.

Placement Examinations

In addition to the placement examinations in *Music Theory* and *Music History*, applicants to the graduate music education program are required to take a placement examination in *Music Education.*

Comprehensive Examination

In addition to the successful completion of a comprehensive examination in music theory and music history, music education candidates must pass a comprehensive examination in music education, and all candidates may expect to be examined in depth in their major area of concentration. Further information as to the nature and scope of the comprehensive examinations may be obtained from the advisor or department chairperson.

Program Requirements

Program requirements are being substantially modified at the time of publication of this catalog. Applicants should contact the chair of the Music Education Department. The Music Education curriculum is based on the assumption that music educators should have a comprehensive knowledge of the subject matter of music, an awareness of current theory and practice in music education and a familiarity with recent developments in general education; particularly in administration, supervision, curriculum and research.

74-596	Introduction to Graduate Study in Music	3
	Applied Music	2,2
	Ensemble	1,1
	Music Theory Elective	3
	Music History Elective	3
	Education Elective*	3
73-551	Research in Music Education	3
	Music Education Electives (minimum of 4 courses)	12
	OR	
	Music Education Electives (3 courses)	9
	plus Music Education Workshops (1)	3
	OR	
	Music Education Electives (2 courses)	6
	plus Music Education Workshops (2)	6
73-796	Thesis	3

* College of Education

Performance Department

Anthony Mele, Professor and Chairperson; B.M., Ithaca College; M.M., Boston University
Faculty: David Martins, Associate Professor, Woodwinds and Conducting; B.M., Eastman School of Music; M.M., University of Lowell; William Moylan, Associate Professor, Sound Recording Technology; B.M., Peabody Conservatory, Johns Hopkins University; M.M., University of Toronto; D.A., Ball State University; Ingul Ivan Oak, Associate Professor, Voice; B.M., M.M., New England Conservatory; Natalo Paella, Professor, Trumpet; B.M., Louisiana State University; M.M. New England Conservatory; Kay George Roberts, Professor, Conducting & Strings; B.A., Fisk University; M.M., M.M.A., D.M.A., Yale University; Rawn W. Spearman, Professor, Music Business; B.S., Florida A.& M.; M.A., Ed.D., Columbia University; Robert White, Associate Professor, Choral Ensembles and Conducting; B.M., New England Conservatory; A.M., Harvard University; Ph.D., Boston University.

Master of Music in Performance

Objectives

The Master of Music degree in Performance is designed to create and maintain the highest level of instruction; to offer courses that are both intellectually stimulating and artistically challenging; to develop performance skills and provide students the experience of performing in large and small ensembles as well as solo recitals; to guide the students' course of study by developing programs that focus directly on attaining a level of professional competence which will help ensure success upon completion of the degree.

Admission Requirements

In addition to the admission requirements for all applicants to the Master of Music degree program, applicants to the Master of Music degree in Performance must accomplish the following:

Auditions

Auditions are held on specific published dates during each academic year, and applicants who meet the general admission criteria will be invited to attend the next scheduled audition following processing of the application materials. Applicants who live at too great a distance may submit a tape directly to the Coordinator of Graduate Studies, but will be expected to audition in person at the beginning of their initial semester of matriculation. Vocal performance applicants must demonstrate proficiency in French, German, and Italian diction.

Admission Requirements

Letters of Recommendation

The three required letters of recommendation submitted with the Graduate School application should be from persons in a position to evaluate the musical skill and accomplishment of the applicant.

Program Requirements

74-596	Introduction to Graduate Study in Music	3
	Applied Music	16
	Ensemble	8
	Electives in Music (500 level and above)	6
	Recital*	

* Two public recitals and the submission of written program notes required.

Master of Music in Performance, Conducting Option

Objectives

The Master of Music degree in Performance, conducting option, is designed to create and maintain an environment of instruction, opportunity and artistic endeavor in which students can develop their individual conducting skills to a level of professional competence fully supported by thorough music knowledge, within the context of a program flexible enough to be responsive to the goals and aspirations of each individual student.

Admission Requirements

Auditions

In addition to the admission requirements for all applicants to the Master of Music degree program, applicants to the Master of Music in Performance, conducting option degree program will be auditioned in both conducting and the applicant's major medium of performance. Those who live at too great a distance may submit video and audio tapes, to the Coordinator of Graduate Studies, but will be expected to audition in person at the beginning of the initial semester of matriculation. Applicants must also present evidence of undergraduate studies in the following areas:

a. conducting,
b. instrumentation and/or orchestration,
c. studies in several areas of music performance representative of the families of musical instruments, i.e., strings, woodwinds, etc.

Letters of Recommendation

The three required letters of recommendation submitted with the Graduate School application should be from persons in a position to evaluate the musical skills and accomplishments of the applicant, as well as the applicant's potential as a conductor.

Program Requirements

74-596	Introduction to Graduate Study in Music	3
	Applied Music	2,2
	Ensembles	1,1
75-550	Seminar in Instrumental Conducting Techniques	3
75-552	Seminar in Choral Conducting Techniques	3
75-654	Seminar in Instrumental Literature	3
75-656	Seminar in Choral Literature	3
75-650	Conducting Practicum & Seminar I*	3
75-652	Conducting Practicum & Seminar II*	3
	Music Electives	6

* Conducting proficiency must be demonstrated while the student is enrolled in the practica courses. Conducting Practicum & Seminar II involves a public conducting performance and the presentation of a related analytical document, which are judged by a panel of assigned faculty. Conducting Practicum & Seminar II is usually completed during the final semester of residence, and is a terminal requirement for the degree.

Music Theory & History – Department of Academic Studies

Course Offerings in Music Theory

71-500 Theory Review (3-0)3
A review of common-practice part writing and analysis. Credit cannot be applied toward the Master of Music degree requirements.

71-501 Analytical Techniques (3-0)3
Formal, contrapuntal and harmonic analysis of common practice repertoire.

71-503 Theoretical Concepts (3-0)3
A study of major concepts in music theory from Rameau to the present.

71-526 Analysis of Contemporary Music (3-0)3
Formal, contrapuntal and harmonic analysis of twentieth century repertoire, both serial and non-serial.

71-601 Topics in Common Practice Analysis (3-0)3
Pre-requisite: 71-501
Exploration of individual topics in theory and compositional technique linked to an area of historical interest to the student.

71-626 Topics in Contemporary Musical Analysis (3-0)3
Pre-requisite: 71-526 or permission of instructor.
Exploration of individual topics in theory and compositional technique linked to a twentieth-century area of special interest.

71-795 Directed Study in Composition (Thesis) (3-0)3
Individual projects in graduate level composition. The course may be repeated for credit. Permission of the instructor is required.

Course Offerings in Music History and Literature

74-539 Eighteenth and Nineteenth Century American Music (3-0)3
Examination of various aspects of American art music during its formative decades.

74-548 J.S. Bach (3-0)3
Representative music of the composer. Emphasis on the stylistic traits and latest research reordering the chronology of Bach's work.

74-549 Mozart (3-0)3
An in-depth study of the development of Mozart's compositional style through an examination of representative works.

74-564 History of Music Theory (3-0)3
A survey of the main currents of musical notation, theory and philosophy from the classical and patristic philosophers to the present.

74-567 Musicology and Research I (3-0)3

74-568 Musicology and Research II (3-0)3

74-596 Introduction to Graduate Study in Music (3-0)3
Research techniques, bibliography, form and style in the preparation of formal scholarly papers in music.

74-597 Topics in Musicology I (3-0)3

74-598 Topics in Musicology II (3-0)3

74-661 Seminar in Medieval Music (3-0)3

74-662 Seminar in Renaissance Music (3-0)3

74-663 Seminar in Baroque Music (3-0)3

74-664 Seminar in Music of the Classic Period (3-0)3

74-665 Seminar in Romantic Music (3-0)3

74-666 Seminar in Twentieth Century Music (3-0)3

74-667 Seminar in Musicology (3-0)3

74-668 Seminar in Musicology (3-0)3

74-796 Directed Study (Thesis) in Musicology (3-0)3

Music Education – Department of Music Education

*Course Offerings in Music Education**

** Subject to program modifications.*

73-551 Research in Music Education (3-0)3
Methods of scientific inquiry in music education. The gathering, correlating, evaluation and reporting of quantitative and qualitative data. Experimental designs in music education. Preparation of thesis prospectus.

73-570 Seminar in Administration and Supervision of Music Education (3-0)3
Lectures, readings, discussion, and individual research projects on a myriad of topics relevant to administration and supervision in music education, K-12.

73-573/589 Workshops in Music Education (3-0)3
Specific concentrated experiences in various facets of music education skills, including Orff (573), Kodaly (580), beginning and advanced; Strings (582); Brass (583); Woodwinds (584); Marching Bands (585); Bands (596); Orchestra (587); Choral (588); Music Theater; Computer Applications (589). Workshops are generally conducted during the summer in two-week, all day sessions.

73-590/599 Workshops: Special Areas (3-0)3
Specific concentrated experiences in specialized facets of music education conducted by visiting or resident experts in the area. Areas are of an exceptional nature; e.g., Dalcroze Eurhythmics, Learning Disabled Child and Music, are offered as announced.

73-601 Seminar in Music Education (3-0)3
Lectures, readings, discussion, and individual research projects on a range of topics in music education including but not restricted to the following: (1) Current issues in music education (2) Curricular and technological innovations (3) Principles and practices of humanistic education, the affective domain, and developments in educational philosophy and psychology (4) New roles and expectations for teachers and learners in a changing society.

73-796 Directed Study (Thesis) in Music Education (3-0)3

Performance – Department of Performance

Course Offerings in Performance

72-501/502 Applied Keyboard IX, X (1/2-10)2

72-511/512 Applied Voice IX, X (1/2-10)2

72-521/522 Applied Woodwinds IX, X (1/2-10)2

72-531/532 Applied Brass & Percussion (1/2-10)2

72-541/542 Applied Strings IX, X (1/2-10)2

72-551/552 Performance Keyboard VII, VIII (1-20)4

72-561/562 Performance Voice VII, VIII (1-20)4

72-571/572 Performance Woodwinds VII, VIII (1-20)4

72-581/582 Performance Brass & Percussion VII, VIII (1-20)4

72-591/592 Performance Strings VII, VIII (1-20)4

72-593/594 Applied Music (1/2-10)2

72-651/652 Performance Keyboard IX, X (1-20)4

72-661/662 Performance Voice IX, X (1-20)4

72-671/672 Performance Woodwinds IX, X (1-20)4

72-681/682 Performance Brass & Percussion IX, X (1-20)4

72-691/692 Performance Strings IX, X (1-20)4

72-693/694 Performance Applied Music (1-20)4

75-540 Meaning & Context: Issues in Music Perception (3-0)3
Study of fundamental philosophical, psychological and scientific issues which affect the musician's ability to think and act critically in matters concerning the performance, apprehension and pedagogy of the musical art.

75-550 Seminar in Instrumental Conducting Techniques (3-0)3
A study of analytical, rehearsal and baton technique in reference to the instrumental conductor. Program selection, performance practice and artistic interpretation are also included in an interactive seminar format.

75-552 Seminar in Choral Conducting Techniques (3-0)3
A study of analytical, rehearsal and baton technique in reference to the choral conductor. Vocal techniques, program selection, performance practice and artistic interpretation are also included in an interactive seminar format.

75-595 Directed Study and Research in Performance 3-0)3

75-650 Conducting Practicum and Seminar I (3-0)3
An extension of the materials and skills developed in Literature and Techniques Seminars, through practical application, under faculty direction, in conjunction with one or more performing ensembles.

75-652 Conducting Practicum and Seminar II (3-0)3
A continuation of 75.650 to a more advanced level, culminating in the presentation of a public conducting performance and a related analytical document.

75-654 Seminar in Instrumental Literature (3-0)3
A study of stylistic elements, orchestration, formal structure, problem analysis and historical perspective in a selection of standard works.

75-656 Seminar in Choral Literature (3-0)3
A study of style, structure, text and historical perspective in relation to the main body of literature for chorus and orchestra. Independent research is a primary element of this course.

75-695 Directed Study and Research in Performance (3-0)3

75-696 Directed Study and Research in Performance (3-0)3

75-796 Directed Study and Research in Performance (3-0)3

76-501 Graduate Vocal Ensemble (0-2)1

76-502 Graduate Instrumental Ensemble (0-2)1

76-601 Graduate Vocal Ensemble (0-4)2

76-602 Graduate Instrumental Ensemble (0-4)2

(Graduate students may fulfill ensemble participation requirements through membership in such performing organizations as Orchestra, Wind Orchestra, Wind Sinfonia, Chamber Singers, etc., or with permission through participation in combinations of smaller, more specialized ensembles.)

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Muktil Das
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Leslie Dawson
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Rudolph Deanin
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George Dery
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Thomas Devine
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Alan Doerr
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Alfred Donatelli
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Joseph Dorsey
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Craig Douglas
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Janet Douglas
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Kathleen Doyle
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Stephen Driscoll
Plastics Engineering
Marian Dubrule
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Richard Ducharme
Management
John Duffy
Mechanical Engineering
David Eberiel
Biology
Nelson Eby
Earth Science
James Egan
Physics

Ellen Eisen
Work Environment
Michael Ellenbecker
Work Environment
Joan M. Ellis
Lydon Library
Richard Eppler
Chemical Engineering
Alma Espinosa
Music
Susan Faraji
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Frederic Faudie
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Charles Feeney
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Michael Fiddy
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Michael Frechette
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Stuart Freedman
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May Futrell
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Graduate School Calendar, 1990-1991

University of Lowell

Graduate School Academic Calendar

FALL 1990

(subject to change)

August 27, Monday
Registration for new students begins

August 30, Thursday
Registration for new students ends

September 3, Monday
Labor Day (University closed)

September 4, Tuesday
Fall classes begin

September 17, Monday
Last Day for registered students to:
1) add a course (if previously registered),
2) change sections within a course,
3) drop a course without record
4) change from audit to credit,
5) petition for health insurance waiver.

September 21, Friday
Last day to submit Advanced Degree Clearance Form for summer degree

October 8, Monday
Columbus Day (University closed)

October 9, Tuesday
Monday class schedule
Monday schedule for evening classes*

October 19, Friday
Make-up date for evening classes*

October 29, Monday
Advising period for spring registration begins

November 2, Friday
Make-up date for evening classes*

November 9, Friday
Advising period for spring registration ends

November 12, Monday
Veterans Day (University closed)

November 13, Tuesday
Registration for spring semester begins
Monday schedule for evening classes*

November 15, Thursday
Registration for spring semester ends

November 16, Friday
Make-up date for evening classes*

November 21, Wednesday
Thursday class schedule
Thanksgiving recess begins - 6:00 p.m.

November 26, Monday
Classes resume

November 28, Wednesday
Last day to drop classes with "W"

December 12, Wednesday
Last day of fall semester classes
Last day for faculty to file grade change forms for incomplete grades for spring and summer courses

December 13, Thursday
Fall semester examinations begin

December 20, Thursday
Last day to submit Advanced Degree Clearance Form for fall degree

December 21, Friday
Fall semester examinations end

* This refers to all courses, such as Mathematics, Electrical Engineering, and Management, which meet after 6 p.m. in rooms on the North or South campus, where schedule changes might conflict with undergraduate courses offered through Continuing Education.

Spring 1991

(Subject to Change)

January 14, Monday
Registration for new students

January 17, Thursday
Registration for new students ends

January 21, Monday
Martin Luther King Day (University closed)

January 22, Tuesday
Spring classes begin

January 25, Friday
Last day for late registration (3 p.m.)

February 4, Monday
Last day for registered students to
1) add a course (if previously registered),
2) change sections within a course,
3) drop a course without record,
4) change status from audit to credit, or
5) petition for health insurance waiver.

February 18, Monday
Washington's Birthday (University closed)

February 19, Tuesday
Monday class schedule

February 22, Friday
Monday class schedule*

March 16, Saturday
Spring Recess begins

March 25, Monday
Classes resume

April 1, Monday
Advising period for fall registration begins

April 15, Monday
Patriot's Day (University closed)

April 19, Friday
Advising period for fall registration ends

April 22, Monday
Pre-registration for fall semester begins

April 25, Thursday
Pre-registration for fall semester ends

April 26, Friday
University Day (no classes)

May 2, Thursday
Last day to submit clearance form for June degree

May 10, Friday
Last day of spring semester classes

May 11, Saturday
Spring semester examinations begin

May 18, Saturday
Spring semester examinations scheduled

May 20, Tuesday
Spring semester examinations end

May 27, Monday
Memorial Day (University closed)

June 2, Sunday
University Commencement

* This refers to all courses, such as Mathematics, Electrical Engineering, and Management, which meet after 6 p.m. in rooms on the North or South campus, where schedule changes might conflict with undergraduate courses offered through Continuing Education.

Graduate School Calendar, 1991-1992

Fall 1991
(subject to change)

August 26, Monday
Registration for new students begins

August 29, Thursday
Registration for new students ends

September 2, Monday
Labor Day (University closed)

September 3, Tuesday
Fall classes begin
September 16, Monday
Last Day for registered students to:
1) add a course (if previously registered),
2) change sections within a course,
3) drop a course without record,
4) change from audit to credit, or
5) petition for waiver of health insurance.

September 20, Friday
Last day to submit Advanced Degree Clearance Form for summer degree

October 14, Monday
Columbus Day - University closed

October 15, Tuesday
Monday class schedule

October 18, Friday
Make-up date for evening classes*

October 28, Monday
Advising period for spring registration begins

November 1, Friday
Make-up date for evening classes*

November 8, Friday
Advising period for spring registration ends

November 11, Monday
Veterans Day (University closed)

November 12, Tuesday
Registration for spring semester begins
Monday schedule for evening classes*

November 14, Thursday
Registration for spring semester ends

November 15, Friday
Make-up date for evening classes*

November 27, Wednesday
Last day to drop classes with "W"
Friday class schedule
Thanksgiving recess begins - 6:00 p.m.

December 2, Monday
Classes resume

December 12, Thursday
Last day of fall semester classes.
Last day for faculty to file grade change forms for incomplete grades for spring and summer courses

December 13, Friday
Fall semester examinations begin

December 19, Thursday
Last day to submit Advanced Degree Clearance Form for fall degree

December 21, Saturday
Fall semester examinations end
* This refers to all courses, such as Mathematics, Electrical Engineering, and Management, which meet after 6 p.m. in rooms on the North or South campus, where schedule changes might conflict with undergraduate courses offered through Continuing Education.

Spring 1992
(Subject to Change)

January 13, Monday
Registration for new students

January 16, Thursday
Registration for new students ends

January 20, Monday
Martin Luther King Day (University closed)

January 21, Tuesday
Spring classes begin

January 24, Friday
Last day for late registration (3 p.m.)

February 3, Monday
Last day for registered students to
1) add a course (if previously registered),
2) change sections within a course,
3) drop a course without record, or
4) change status from audit to credit,
5) petition for waiver of health insurance.

February 17, Monday
Washington's Birthday (University closed)

February 18, Tuesday
Monday class schedule

February 22, Friday
Monday class schedule for evening classes*

March 14, Saturday
Spring Recess begins

March 23, Monday
Classes resume.
Advising period for fall registration begins

April 10, Friday
Advising period for fall registration ends

April 13, Monday
Pre-registration for fall semester begins

April 16, Thursday
Pre-registration for fall semester ends

April 20, Monday
Patriot's Day (University closed)

April 24, Friday
University Day (no classes)

April 30, Thursday
Last day to submit clearance form for June degree

May 8, Friday
Last day of spring semester classes

May 9, Saturday
Spring semester examinations begin

May 16, Saturday
Spring semester examinations scheduled

May 18, Monday
Spring semester examinations end

May 25, Monday
Memorial Day (University closed)

May 31, Sunday
University Commencement

* This refers to all courses, such as Mathematics, Electrical Engineering, and Management, which meet after 6 p.m. in rooms on the North or South campus, where schedule changes might conflict with undergraduate courses offered through Continuing Education.

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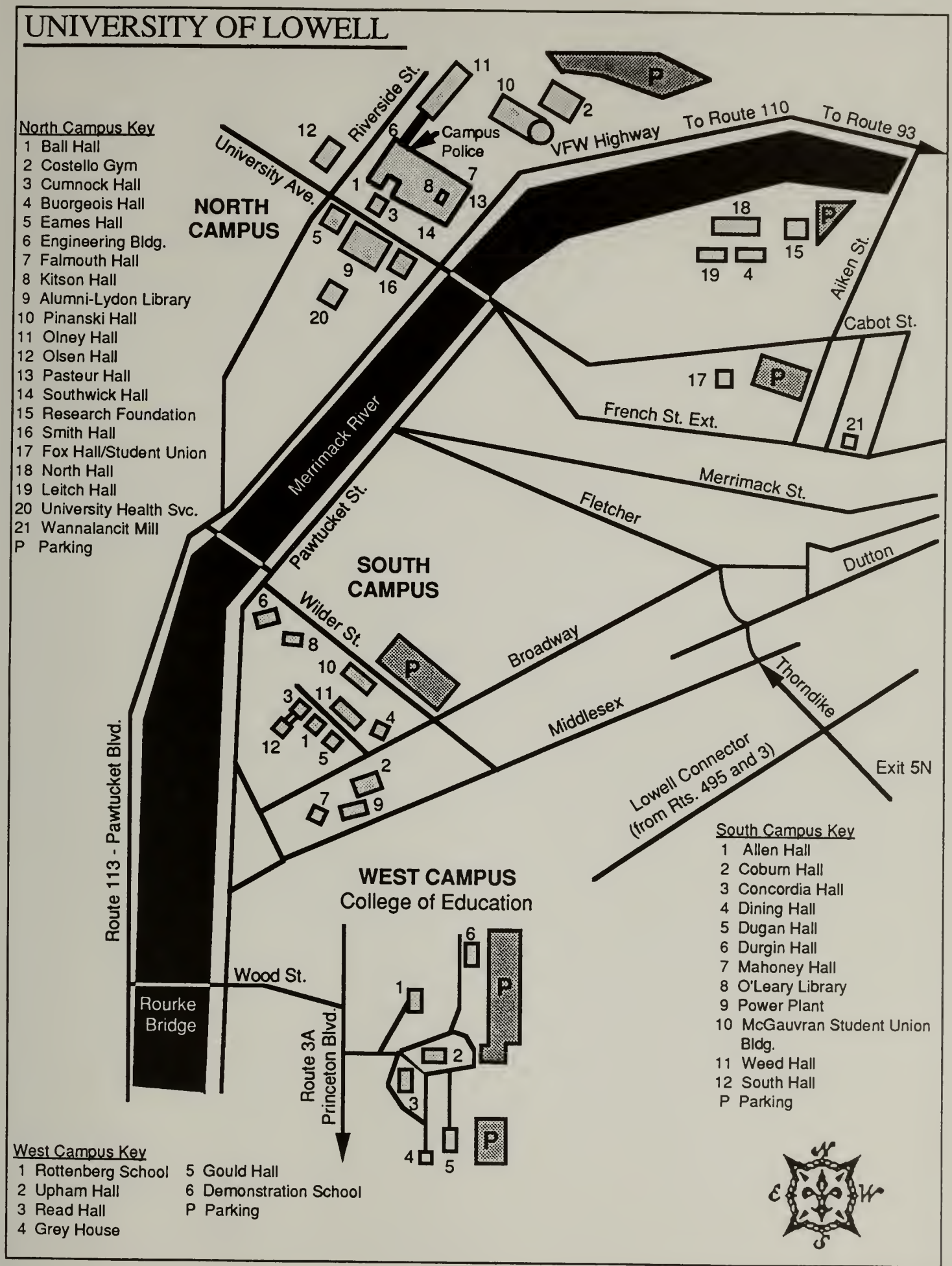
UNIVERSITY OF LOWELL



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